

**NATIVE AND NONNATIVE FISH USE OF TWO GRAVEL-PIT
PONDS CONNECTED TO THE UPPER COLORADO RIVER AT
29-5/8 ROAD NEAR GRAND JUNCTION, COLORADO**



**Final Report
December 1997**

U. S. Fish and Wildlife Service

98-007135

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Recovery Program Project Number CAP-6-GP

Final Report

December 1997

Prepared for

**Recovery Implementation Program
for Endangered Fishes in the
Upper Colorado River Basin**

**Bob D. Burdick
Fishery Biologist**

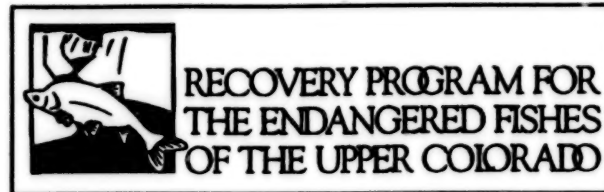
and

**Joe Flair, Meredee Lloyd, Brian Scheer
Biological Science Technicians**

**U. S. Fish and Wildlife Service
Colorado River Fishery Project
764 Horizon Drive, South Annex A
Grand Junction, Colorado 81506-3946**

This study was funded by the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin. This Program is a joint effort of the U. S. Fish and Wildlife Service, U. S. Bureau of Reclamation, Western Area Power Administration, states of Colorado, Utah, and Wyoming, Upper Basin water users, environmental organizations, and the Colorado River Energy Distributors Association.

Recovery Implementation Program for the Endangered Fishes of the Upper Colorado River Basin, U. S. Fish and Wildlife Service, P. O. Box 25486, Denver Federal Center, Denver, Colorado 80225.



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Suggested citation:

Burdick, B. D., J. Flair, M. Lloyd, and B. Scheer. 1997. Native and nonnative fish use of two gravel-pit ponds connected to the Upper Colorado River at 29-5/8 Road near Grand Junction, Colorado. Final Report prepared for the Recovery Implementation Program for Endangered Fishes in the Upper Colorado River Basin. U. S. Fish and Wildlife Service, Colorado River Fishery Project, Grand Junction, Colorado. 32 pp + appendices.

Cover Photograph: Oblique aerial view looking northeasterly at Gardner Pond in the right foreground and Hotspot Pond in the left background, 9 December 1996. The Colorado River flows from right to left in the immediate foreground. Photo by B. D. Burdick.

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List of Key Words: floodplain habitat, ponds, native fishes, nonnative fishes, Upper Colorado River, electrofishing, trammel nets, fyke nets, restoration, connectivity, recontouring

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ACKNOWLEDGMENTS

The authors wish to thank those who participated in this project. Mike Baker, Kathy Holley, Chuck McAda, Mike Montagne, Toby Mourning, and Doug Osmundson assisted in fish sampling. Dan Crabtree, Bureau of Reclamation, Grand Junction, Colorado, provided engineering support and coordinated the construction and excavation of the connection channel at Gardner Pond. Steve McCall, Bureau of Reclamation, Grand Junction, was responsible for conducting NEPA compliance. Both Dan and Steve obtained the necessary county, state, and federal permits. This included a floodplain permit from Mesa County, a NPDES discharge permit from the State of Colorado, Department of Health, and a 404 permit from the U. S. Army Corps of Engineers. Blake Bailey, Burt Ives, Bob Levine, and Ted Juntilla, Bureau of Reclamation, Grand Junction, provided surveying support.

The State of Colorado, Division of Parks and Outdoor Recreation, owner of property surrounding Gardner Pond, and Mr. C. W. Van Wagner, owner of the area around Hotspot Pond at 29-5/8 Road, permitted access to the site. Ed Gardner, Whitewater Building Materials, Corp., Grand Junction, coordinated and facilitated agreements with Kurt Mill of the Division of Parks and Outdoor Recreation and with Colorado Mined Land Reclamation. Pat Nelson, floodplain habitat restoration coordinator for the Recovery Program, Denver, Frank Pfeifer, Fish and Wildlife Service, and Bob Norman, Bureau of Reclamation, Grand Junction, provided administrative support. The draft report was peer-reviewed by Dr. Richard Valdez, Dr. Richard Wydoski, and Patrick Martinez.

EXECUTIVE SUMMARY

The purpose of this study was to evaluate the seasonal composition and density for native and nonnative fishes in two ponds with different bottom shapes and configurations--one pond was a gravel-pit depression that holds water year-round (Gardner Pond) and the other was slightly graded toward the mainstem river but holds water seasonally (Hotspot Pond)--and both are connected to the mainstem Colorado River in the same general stream reach. The objective of the study was to determine which pond configuration and bottom shape might benefit endangered and other native fishes and reduce or eliminate nonnative fish that are thought to adversely impact endangered fishes. Prior to the biological evaluation, a portion of the dike of Gardner Pond, which was a former gravel-pit depression, was removed and a channel excavated to connect the pond with the river to provide fish access.

Nineteen adult Colorado squawfish were captured from both Gardner and Hotspot ponds in 1996. In Gardner Pond, three were captured during pre-runoff, seven during runoff, and two during post-runoff. In Hotspot Pond, one was collected during pre-runoff, six during runoff, and none during post-runoff. During pre-runoff, nonnative sub-adult and adult fish comprised 85% and 97% of the catch in Gardner and Hotspot ponds, respectively. The most common fishes collected in Gardner Pond were: black bullhead (36%), white sucker and common carp (19% each). Species relative abundance was similar for Hotspot Pond: black bullhead (31%), common carp (26%), and white sucker (18%). During runoff, native fish comprised 37% and 13% of the catch in Gardner and Hotspot ponds, respectively. The most common fishes collected in Gardner Pond were flannemouth sucker (33%), green sunfish (24%), and white sucker (21%). The most common fishes collected in Hotspot Pond were white sucker (33%) and black bullhead (18%). The most common native fish collected in Hotspot Pond during runoff was flannemouth sucker (5%). During post-runoff, nonnative fish comprised 99% and 98% of the catch in Gardner and Hotspot ponds, respectively. The most common nonnative fishes collected from Gardner Pond were black crappie (24%), common carp (20%), white sucker (20%), and black bullhead (15%). For Hotspot Pond, black bullhead (28%), white sucker (21%), largemouth bass (19%), and common carp (18%) were the most commonly caught fishes.

Nine different species of mostly small, young-of-the-year fish as well as sub-adults and adults of some smaller species such as red shiner, sand shiner, and western mosquitofish were collected with seines in July to determine annual reproduction of young-of-the-year fishes. A total of 832 fish representing eight species were collected in Gardner Pond; 413 fish representing eight species were collected in Hotspot Pond. Five nonnative fish species (black bullhead, largemouth bass, black crappie, green sunfish, and western mosquitofish) had successfully reproduced in both ponds. Numerically, the eight fish species collected in descending order in Gardner Pond were black crappie (40%), black bullhead (32%), largemouth bass (17%), western mosquitofish (7%), green sunfish (3%), common carp, red shiner, and bluegill (each < 1%). In Hotspot Pond, the eight most common species were largemouth bass (35%), western mosquitofish (30%), black crappie (22%), green sunfish (8%), black bullhead and sand shiner (each 2%), red shiner (1%), and common carp (< 1%). Densities (fish/10m²) for the five most common fishes collected in Gardner Pond were: black crappie (6.2), black bullhead (5.1), largemouth bass (2.7), western mosquitofish (1.2), and green

sunfish (0.4). For Hotspot Pond, largemouth bass (2.0), western mosquitofish (2.1), black crappie (1.2), green sunfish (0.4), and black bullhead (0.1).

The following conclusions from this research were: 1) the species composition of both ponds was predominantly nonnative during all three sampling periods, 2) native fishes used the two connected ponds mostly during runoff, 3) five species of sub-adult and adult nonnative fishes moved between the two ponds that were connected to the river; white sucker and largemouth bass migrated the most between the two ponds. Roundtail chub was the only native fish to move between the two ponds, 4) within four months following draining of Gardner Pond, removal of nonnative fishes, and construction of a connection channel, nonnative fishes invaded and recolonized the pond, and within eight months, five species of nonnative fishes had successfully reproduced in Gardner Pond. Ponds in the 10-, 50-, and 100-year floodplain that have bottoms shaped and contoured as depressions are havens that provide perennial, off-channel habitats for nonnative fishes to grow and reproduce. Ponds that are depressions and that are connected to the river allow sub-adult and adult fish uninhibited access to the river and to other off-channel habitats connected to the river. Ponds with depressions provide a constant supply source of nonnative fish that can potentially escape to the mainstem river. While depressions benefit native fishes for a period only during runoff, nonnative fishes appear to benefit more from such perennial, lentic habitats, and 5) Hotspot Pond did not drain following runoff in 1996. If ponds are reclaimed, steeper bottom slopes than that found in Hotspot Pond will be required for ponds to drain during high-flow years to reduce or eliminate perennial habitat for nonnative fishes.

Recommendations were to: 1) avoid connecting isolated ponds to the river that are irregular-shaped, deep depressions because such habitats provide perennial havens for nonnative fishes. If deep-depression habitats cannot be rehabilitated by recontouring and reshaping to provide seasonal, ephemeral habitat, or sloped to concentrate and harvest captive-reared fish, they should be sufficiently diked to prevent escapement of nonnative fishes such as centrarchids and ictalurids, and 2) back-fill gravel-pit ponds so that they are sloped to flood and drain seasonally and reconnect them to the mainstem river to benefit native fishes and to reduce proliferation of nonnative fishes. Such modifications would allow the floodplain to function as an ephemeral wetland and may be more cost-effective and practical for managing and controlling nonnative fishes than long-term control measures such as screening, chemical treatment, or mechanical pumping and removal of nonnative fish species. Whenever floodplain habitats are connected to the river, hydrological access for fish should be by surface connection. Underground culverts and pipes should be avoided because some native fish might be shy and will not use such structures.

Alternative management options that should be considered by the Recovery Program as habitat improvements to assist recovery of Colorado River endangered fishes included: 1) coordinating Recovery Program efforts with the U. S. Army Corps of Engineers, Colorado Mined Land Reclamation, and gravel-pit companies to restore gravel-mining areas to function as historical terraces to benefit native fishes, 2) notching dikes and levees protecting gravel pits by reconnecting former floodplain habitats without deep depression ponds with the river to enhance or restore the natural function of the river ecosystem. Dikes and levees constructed to protect gravel-mining operations could be removed following gravel

mining to permit reconnection of the floodplain and the river. The floodplain could then function as it did historically, recreating new in-channel habitats. Some of the features created would be flow-through side channels that might create a complex of habitat types. Another reason for modifying gravel-pits protected by levees and dikes to allow these habitats to communicate with the river during runoff would be flood control. Flood-control management strategies would be to notch levees and dikes to allow inundation of low-lying areas and also reclaim gravel-pit ponds as sloped terraces or side channels. Restoring gravel pits to function as historical terraces or side channels may not only benefit native fishes but may actually provide county, state, and federal agencies more flexibility in managing spring runoff during high-flow years along riparian areas in low-density population areas. Notching old levees and dikes at strategic locations could provide some level of protection from flooding to agricultural land, and residential and recreational structures (i. e., set-back dikes) and also provide access to floodplain habitats to various life stages of endangered fishes. 3) acquiring Hotspot and Pickup ponds, two gravel-pits presently connected to the mainstem Colorado River that are used during spring runoff by adult Colorado squawfish, and investigating opportunities to recontouring and reshaping the bottom of these two ponds to enhance seasonal habitat for endangered fish and eliminate perennial habitat for nonnative fishes, and 4) using deeper depression ponds as grow-out ponds for captive-rearing of endangered fishes. Such ponds could serve as a "half-way house" for captive-reared razorback sucker juveniles from the hatchery-pond environment where they would be reared as family lots until they could be PIT-tagged and stocked into the river. The ponds would have to be drained and the bottoms sloped so that seining or trap nets could be used to concentrate and harvest captive-reared fish for stocking.

INTRODUCTION

General

Historically, upper Colorado River basin floodplains were inundated annually by flows during spring runoff, but today floodplains are not regularly connected to the river because of channelization by levees, dikes, or rip-rap near population centers and in agricultural areas. Introduced salt cedar or tamarisk (*Tamarix* spp.) has become established along the shoreline of major rivers resulting in sediment deposition and stabilized banks that further reduce the connectivity of the river with historic flooded bottomlands (Graf 1978). The periodicity of out-of-channel flooding in the upper Colorado River has dramatically decreased following the onset of transmountain water diversions, irrigation diversions, and the construction of mainstem dams (Osmundson and Kaeding 1991). The construction of dikes coupled with the reduction of high spring flows has altered the natural hydrograph and either reduced or eliminated regular flooding of bottomlands. It is believed that flooded bottomlands may have served as nursery areas for the razorback sucker¹ (McAda 1977; Osmundson and Kaeding 1991). In addition, Osmundson and Kaeding suggested that oxbow lakes and flooded pastures in the Grand Valley near Grand Junction, Colorado, were historically the primary spawning habitats of the razorback sucker. They also suggested that low velocity, off-channel habitats were used by adult Colorado squawfish during high streamflows.

Numerous studies (Grawboski and Hiebert 1989; Tyus and Karp 1989; Wydoski and Wick 1994) have suggested the importance of seasonal flooding to river productivity. Other studies have suggested that flooded bottomlands were important to adult razorback sucker for feeding prior to and after spawning and for the rearing of their young (Tyus and Karp 1989). Adult fish may have used these off-channel habitats for "velocity shelters" to escape the high water velocities from the spring runoff.

The turbid rivers in the upper basin are not very productive for zooplankton that are essential for survival during the early life stages of the razorback sucker. When compared to the riverine environment and river backwaters, inundated bottomlands produce the highest densities of zooplankton (Grabowski and Hiebert 1989; Mabey and Shiozawa 1993). Although predation has been documented to be a limiting factor in survival of larval razorback sucker in the lower basin (Minckley et al. 1991), starvation may also limit survival (Marsh and Langhorst 1988; Papoulias and Minckley 1990). It is hypothesized that the loss of these productive flooded bottomland habitats appears to be limiting the recruitment of the razorback sucker in the upper Colorado River basin because of the lack of the right sizes of food organisms at the right time and in sufficient quantity (Wydoski and Wick 1994).

Flooded bottomland habitats occur in broad valleys along low gradient stream reaches. Bottomlands are off- or out-of-channel habitats that include

¹ Scientific names and two-letter codes of all fishes mentioned in this report are given in Appendix A; Table A.1. Only common names for these fishes are used in the text.

oxbow lakes, former side channels in broad valley floodplains, ponds, and wetland depressions. During high flow events, some of these off-channel features were temporarily connected to the river in the past. These former natural riverine features could be integrated back into the historic floodplain by removing portions of man-made dikes or natural obstructions (e. g., gravel/sand bars).

Background

Although gravel pits are artificial environments that are typically diked and isolated from the mainstem river, they comprise a large proportion of pond habitats created by gravel-pit mining in the floodplain in some river corridors along the Upper Colorado River. Much of the floodplain habitat in the Upper Colorado River from the Colorado-Utah state line upstream to Rifle, Colorado, on the Colorado River and upstream to Austin on the Gunnison River has been modified by humans either from levee construction or mining gravel. There are four areas along the Upper Colorado River where gravel-mining operations have created numerous pits that vary in size, depth, shape, and orientation to the mainstem river: the Grand Valley between Palisade and Loma, Colorado (15- and 18-mile reaches), between Rifle and Debeque, Colorado, and near Delta, Colorado, on the Gunnison River. For example, Mitchell (1995) identified 243 ponds within 1 mile either side of the Upper Colorado River between Palisade and Loma. He calculated that these ponds totaled approximately 713 surface acres of standing water. Most of these ponds were created either from gravel mining or for sewage treatment plants. More importantly, these ponds are located in the former floodplain. Historical aerial photos of this same area reveal very little gravel-mining activity and ponds as late as 1954. In 1937 and 1954, there were no gravel pits in this reach and only 'virgin' floodplain existed where the 29-5/8 Road gravel-pit pond site occurs today. Even more dramatic is the approximate 15 miles of man-made dikes in this 33-mile stream reach between Palisade and Loma (Irving and Burdick, 1995) that effectively prevent inundation of potential off-channel habitats and fish access to historic floodplain habitat.

During high flow events, some of these ponds have temporarily connected to the river allowing access to fish. However, these ponds that do not have permanent connections to the river have also trapped fish following recession of high flows. Ponds that are reconnected to the river are less likely to trap endangered fishes. Integrating ponds created from gravel-pit mining into the historic floodplain by removing portions of dikes, resloping gravel pits toward the river, and re-establishing connectivity to the river may provide off-channel habitats which are beneficial for effective management of the riverine ecosystem and recovery of endangered fishes.

Most researchers believe that connecting isolated ponds to the river can be seasonally beneficial to endangered fishes. Ponds that are gently graded and connected to the river should be evaluated for their use and benefit for endangered fishes by providing off-channel habitats while reducing or minimizing proliferation of nonnative fishes that may compete with or predate upon endangered fishes. Valdez and Wick (1983) and Osmundson and Kaeding (1991) hypothesized that graded gravel pits that flood during runoff and drain with descending flow may benefit adult razorback sucker and Colorado squawfish by providing feeding, resting, conditioning, and possibly spawning areas. Habitat

METHODOLOGY

Field Sampling

Three different gear types, electrofishing, trammel nets, and trap nets, were used to collect sub-adult and adult fish in both Gardner and Hotspot ponds. Electrofishing was conducted from an outboard-powered, aluminum electrofishing jon boat, equipped with a 5-kilowatt generator and a Coffelt VVP-15 voltage pulsator to adjust the voltage and amperage transmitted to the water. The electrofishing boat used two spherical anodes (about 9-inch diameter) suspended from fiberglass booms in front and two 7-ft cathodes (0.25-inch diameter twisted cable) suspended from each side of the boat. The boat hull was also used as a cathode in conjunction with the droppers. Both the anode and cathode were stainless steel. Investigators used direct current and tried not to exceed 300 volts or 12 amps to minimize injury to fish, while maximizing electrofishing effectiveness. Trammel nets were 1.0- and 1.5-inch bar mesh, with a wall of 10- or 12-inch and 150-ft long. Two different size trap nets were used. The larger size was a series of two, 4 ft X 6 ft, rectangular hoops followed by five circular hoops that were each 4 ft in diameter. A center lead, 4 ft wide X 75 ft long, was attached to a vertical, center brace of the first rectangular hoop. One-inch square mesh netting covered all the hoops and the center lead. The smaller trap nets were a series of two, 3 ft X 4 ft, rectangular hoops followed by five circular hoops that were each 3 ft in diameter. The center lead was approximately 3 ft wide X 50 ft long. Delta netting, 3/8-inch mesh, covered all the hoops and the center lead. Two tapered throats were attached to the first and third circular hoops of both the small and large trap nets.

Sampling with electrofishing, trammel, and trap nets occurred during April, June, and July of 1996 which coincided with pre-runoff, runoff, and post-runoff flow stages of the Colorado River, respectively. Electrofishing was used primarily to collect fish from shorelines around the perimeter of each pond and shorelines of islands. Trammel nets were used to sample mid-water, pelagic habitat, and trap nets were set with one end of the center lead anchored to the shoreline with the hoops extending out into the pond. For each gear type, the numbers of fish by species and age category (sub-adult and adult) were recorded on field data sheets at the end of each sample effort. All Colorado squawfish collected were initially checked for a passive integrated transponder (PIT) tag, weighed (g), measured (total length [TL], mm), and muscle-plugged for contaminant analyses. Colorado squawfish that had not been previously captured were PIT-tagged. All other native and nonnative fishes collected were fin-clipped to obtain recapture data to determine if fish moved between the two ponds. For Gardner Pond, the left pelvic fin was clipped for the first capture, the left pectoral fin for the first recapture, and the upper caudal fin for the second recapture. For Hotspot Pond, the right pelvic fin was clipped for the first capture, the right pectoral fin for the first recapture, and the lower caudal fin for the second recapture.

All fish collections were accompanied with detailed information regarding pond location, date, time of day, water temperature, voltage and amperage output of electrofishing equipment. All fish were released alive. For electrofishing, effort was recorded in seconds which was later converted to hours electrofished. For trammel and trap nets, effort was recorded as total hours of fishing.

Seines (1/8-inch ace mesh, 6-foot wide and 30-feet long) were used to collect post-larval, young-of-the-year fishes in August. Fish that were identified to species afield were counted and released alive. Total lengths of a representative sample of fish collected were recorded. No fish were preserved. The physical parameters recorded for each sample included, 1) length and width of the seine haul, 2) substrate type, 3) and water temperature. Effort was recorded as area swept by the seine (m^2).

Data Compilation and Analysis

Fishery data were recorded on standardized data forms. These data were then stored in the database management system, DBASE III+, to facilitate access and analyses as well as to provide data compatible with the computer system format used by the ISMP database. Computer diskettes containing the corresponding DBASE III+ files from this study are available upon request through the ISMP database manager, FWS, Grand Junction, Colorado.

Capture data for sub-adult and adult fish were analyzed by various methods. Total catch per unit effort (CPUE: total fish collected/total hours sampled [F/h]) was used to determine relative density of fish in electrofishing, trammel, and trap-net collections. CPUE was calculated for each fish species and three sucker hybrids (white sucker X flannemouth sucker, white sucker X bluehead sucker, and bluehead sucker X flannemouth sucker) by pond and sampling period in 1996. Species composition and relative abundance (expressed as a percentage of total numbers) were used to describe the fish community by pond and sampling rotation in 1996. Before a connection channel was excavated between Gardner Pond and the river, the fish community in the pond was inventoried in the summer of 1995 with electrofishing, trammel and trap nets, and seining to determine relative abundance and species composition.

Capture data for small-sized fish collected with seines were reported as total catch per unit effort (CPUE: total fish collected/total area swept by the seine [F/10 m^2]). Species composition and relative abundance were also used to describe the fish community in each pond. Seining was conducted primarily to assess the annual reproduction of young-of-the-year fish from both ponds. Length-frequency graphs were plotted for four nonnative fishes collected with seines to compare the size structure of small-sized fish in both ponds.

RESULTS AND DISCUSSION

Pre-Connection Channel Inventory

During May and August of 1995, the fish community of Gardner Pond was surveyed to determine the percentage of nonnative fish prior to the pond being connected to the river. If the fish population was determined to be predominantly nonnative, they would have to be removed during the draining of the pond and prior to the pond being connected to the river. Of the eleven species captured nine were nonnatives. Approximately 1,494 fishes were captured with nonnative fishes comprising 98% of the catch. The nine nonnative fishes collected in descending order of abundance were black bullhead (42%), green

sunfish (22%), common carp (9%), bluegill (7%), largemouth bass (7%), white sucker (4%), red shiner (3%), black crappie (3%), and channel catfish (1%). The only two native fishes collected were flannemouth sucker and bluehead sucker (1% each; Figure 3). Prior to the pond being connected to the river, it was drained by pumping and all nonnative fish were removed. All native fish were returned to the Colorado River.

In December 1995, Bureau of Reclamation and FWS personnel removed a portion of the dike at the downstream end of Gardner Pond and established a channel to connect this pond with the river to provide access to riverine adult razorback sucker, Colorado squawfish, and other native fishes.

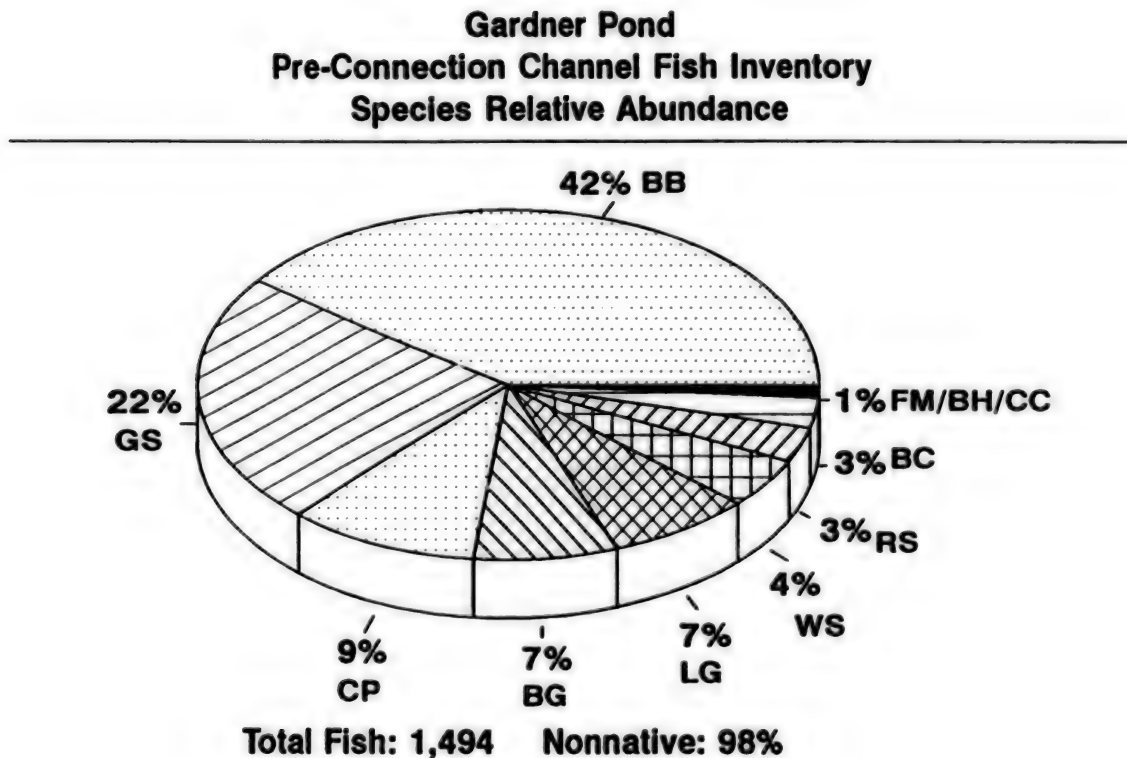


Figure 3. Relative abundance of fishes collected during the summer of 1995 prior to Gardner Pond being connected to the Colorado River. Refer to Appendix A; Table A.1. for the two-letter species code.

Inventory of Large-sized Fishes

Composition and Abundance

Electrofishing, trammel nets, and trap nets mostly captured sub-adults and adults of the larger-sized fish. Of the 21 fishes collected during the entire study, 15 species and three hybrid suckers were collected with these three gear types (Appendix; Table A.1.). Eleven species and two hybrid sucker were nonnative whereas four species and one hybrid sucker were native. Three additional species, red shiner, sand shiner, and western mosquitofish, were collected with seines.

Endangered Fishes. Nineteen adult Colorado squawfish were captured in both Gardner and Hotspot ponds. In Gardner Pond, three were captured during pre-runoff, seven during runoff, and two during post-runoff. In Hotspot Pond, one was collected during pre-runoff, six during runoff, and none during post-runoff. Eleven of these fish had been captured previously (Appendix B; Table B.1.). In Gardner Pond, Colorado squawfish comprised 0.60% of the fish collected during pre-runoff, 2.49% during runoff, and 1.46% during post-runoff. In Hotspot Pond, Colorado squawfish comprised 0.14% during pre-runoff and 1.87% during runoff. Five of these 19 fish were implanted with 360-day LOTEK® radiotags and translocated to the Lower Gunnison River as part of another study to evaluate if adult Colorado squawfish would use the fish passageway at the Redlands Diversion Dam. One Colorado squawfish died in a trammel net. No other endangered fishes were collected.

Pre-Runoff Sampling. Native fish comprised 15% of the 663 fish collected from Gardner Pond whereas only 3% of the 697 fish collected from Hotspot Pond were native (Figure 4). Between 9 and 19 April, the three most common fishes collected from Gardner Pond were black bullhead (36%), and white sucker and common carp (19% each). Species relative abundance was similar for Hotspot Pond: black bullhead (31%), common carp (26%), and white sucker (18%; Table 1).

It was assumed that all fish were removed in December 1995 when Gardner Pond was drained. Data from the April 1996 inventory indicated that nonnative fishes invaded and recolonized Gardner Pond within the 4 months following construction of the connection channel but before the April sampling. Species such as black bullhead, black crappie, green sunfish, and largemouth bass probably originated from neighboring Hotspot Pond.

Runoff Sampling. Native fish used these two connected ponds mostly during runoff. Native fish comprised 39% and 13% of the catch in Gardner and Hotspot ponds, respectively (Figure 4). Of the 282 fish collected in Gardner Pond, the most common fishes collected were flannelmouth sucker (33%), green sunfish (24%), and white sucker (21%). Of the 321 fish collected in Hotspot Pond, the most common were white sucker (33%), black bullhead (18%), and bluegill (13%; Table 2).

Table 1. Catch statistics for fishes collected by electrofishing, trap nets, and trammel nets from Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, during pre-runoff, April 1996.

PRE-RUNOFF (4/9 - 4/19/96)

Common Name	Gardner Pond				Hotspot Pond			
	JUV	ADU	TOTAL	Percentage Composition	JUV	ADU	TOTAL	Percentage Composition
Native								
flannelmouth sucker	36	42	78	11.76	10	2	12	1.72
bluehead sucker	0	1	1	0.15	0	1	1	0.14
roundtail chub	7	12	19	2.87	2	3	5	0.72
Colorado squawfish	0	3	3	0.45	0	1	1	0.14
Nonnative								
black bullhead	240	1	241	36.35	205	13	218	31.28
common carp	2	122	124	18.70	18	167	185	26.54
largemouth bass	1	5	6	0.90	12	21	33	4.73
white sucker	57	72	129	19.46	104	24	128	18.36
black crappie	6	14	20	3.02	15	58	73	10.47
bluegill	5	12	17	2.56	2	26	28	4.02
smallmouth bass	0	0	0	..	0	0	0	..
northern pike	0	0	0	..	0	0	0	..
walleye	0	0	0	..	0	0	0	..
channel catfish	0	1	1	0.15	0	4	4	0.57
green sunfish	22	2	24	3.62	9	0	9	1.29
TOTAL	..	..	663	100.0	..	..	697	100.0

Gardner Pond: % Native: 15.24
% Nonnative: 84.77

Hotspot Pond: % Native: 2.72
% Nonnative: 97.28

Table 2. Catch statistics for fishes collected by electrofishing, trap nets, and trammel nets from Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, during runoff, June 1996.

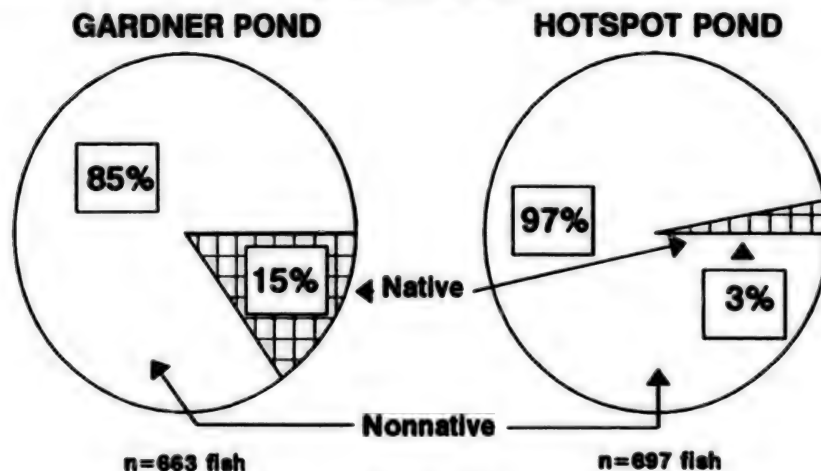
RUNOFF (6/3 - 6/12/96)

Common Name	Gardner Pond				Hotspot Pond			
	JUV	ADU	TOTAL	Percentage Composition	JUV	ADU	TOTAL	Percentage Composition
Native								
flannemouth sucker	59	33	92	32.62	14	3	17	5.30
bluehead sucker	0	0	0	..	0	0	0	..
roundtail chub	2	2	4	1.42	0	2	2	0.62
Colorado squawfish	0	7	7	2.49	0	6	6	1.87
Nonnative								
black bullhead	11	0	11	3.90	58	0	58	18.07
common carp	0	15	15	5.32	0	19	19	5.92
largemouth bass	0	0	0	..	10	5	15	4.67
white sucker	27	33	60	21.28	75	30	105	32.71
black crappie	0	6	6	2.13	0	39	39	12.15
bluegill	0	15	15	5.32	0	41	41	12.77
smallmouth bass	0	1	1	0.35	0	0	0	..
northern pike	0	0	0	..	0	0	0	..
walleye	0	0	0	..	0	0	0	..
channel catfish	0	2	2	0.71	0	3	3	0.93
green sunfish	69	0	69	24.47	16	0	16	4.98
TOTAL	..	..	282	100.0	..	..	321	100.0

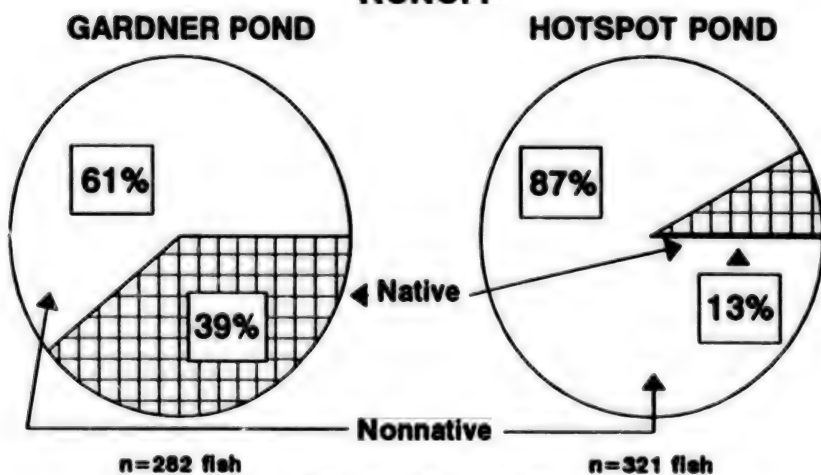
Gardner Pond: % Native: 36.53
% Nonnative: 63.47

Hotspot Pond: % Native: 7.79
% Nonnative: 92.21

29-5/8 ROAD PONDS
Relative Abundance-Sub-adult and Adult Fish--1996
PRE-RUNOFF



RUNOFF



POST-RUNOFF

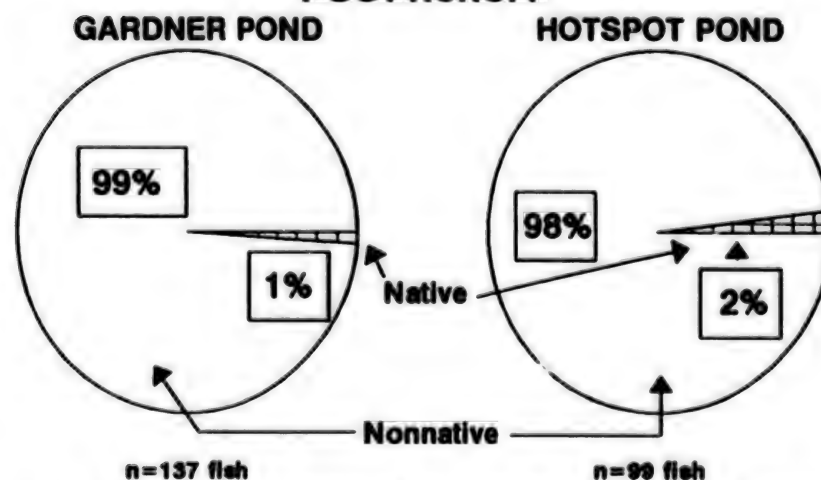


Figure 4. Relative abundance of native and nonnative fishes collected by electrofishing, trap nets, and trammel nets from Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, 9-19 April, 3-12 June, and 16-24 July 1996.

Post-Runoff Sampling. During post-runoff sampling in July, two adult Colorado squawfish were the only native fish caught in Gardner Pond which was 1% of the 137 total fishes collected. These two fish were caught in the connection channel between the pond and river. In Hotspot Pond, the only native fish caught were two juvenile flannemouth sucker that comprised 2% of the 99 fish collected (Figure 4). The most common nonnative fishes captured in Gardner Pond were black crappie (24%), common carp (20%), white sucker (21%), and black bullhead (15%). In Hotspot Pond, the four most common caught fishes were black bullhead (28%), white sucker (21%), largemouth bass (19%), and common carp (18%; Table 3).

Gear Type vs. Species Selectivity

Relative abundance was used to describe the species collected by each gear type (Appendix C; Tables C.1.-C.3.). Of the 448 fish collected with electrofishing from both ponds during the three periods sampled, the most common fishes captured numerically in descending order were common carp (64%), largemouth bass and black bullhead (12% each) and green sunfish (4%). Of the 1,348 fish collected with trap nets, the most common species captured were black bullhead (34%), white sucker (24%), black crappie (12%), and flannemouth sucker (8%). Of the 389 fish collected with trammel nets, the most common fishes captured were white sucker (39%), flannemouth sucker (23%), black bullhead (20%), and common carp (7%).

An attempt was made to determine if one gear type was more selective in capturing certain fishes. Each of the three different gear types used to capture sub-adult and adult fishes appeared to select for certain species. Electrofishing selected for sub-adult and adult carp, largemouth bass, and black bullhead (Table 4; Figure 5). Trap nets captured three times as many fish as either electrofishing or trammel nets. Trap nets selected for black bullhead in addition to white sucker, black crappie, bluegill, and green sunfish. Trammel nets appeared to select more than electrofishing for black bullhead and white sucker. Trap and trammel nets were similarly selective in capturing native fishes such as flannemouth sucker, bluehead sucker, roundtail chub, and Colorado squawfish.

Fish Recaptures

One adult Colorado squawfish (PIT-tag no. 1F413A0066), initially captured in Gardner Pond 11 April, was recaptured twice in Gardner Pond, once on 15 April and again on 11 June (Appendix B; Table B.1.).

Of the 2,152 sub-adult and adult nonnative and native fishes that were fin-clipped in both ponds during 1996, 370 fish were recaptured. Fifty-six percent of the fish were recaptured during the first sampling period, pre-runoff; 31% were recaptured during the second sampling period, runoff; and 13% were recaptured during post-runoff. Numerically, white sucker (127), and black bullhead (76) were the most common fishes recaptured which was 27% and 13%, respectively, of the total number marked (470 and 575) for each of these two species. Of the 90 largemouth bass captured and marked, 21% were recaptured. Approximately 112 fishes that were initially marked in Gardner Pond were

Table 3. Catch statistics for fishes collected by electrofishing, trap nets, and trammel nets from Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, during post-runoff, July 1996.

POST-RUNOFF (7/16 - 7/24/96)

Common Name	Gardner Pond				Hotspot Pond			
	JUV	ADU	TOTAL	Percentage Composition	JUV	ADU	TOTAL	Percentage Composition
Native								
flannelmouth sucker	0	0	0	..	2	0	2	2.02
bluehead sucker	0	0	0	..	0	0	0	..
roundtail chub	0	0	0	..	0	0	0	..
Colorado squawfish	0	2	2	1.46	0	0	0	..
Nonnative								
black bullhead	20	0	20	14.60	27	0	27	27.27
common carp	2	26	28	20.44	3	15	18	18.18
largemouth bass	8	9	17	12.41	12	7	19	19.19
white sucker	21	6	27	19.71	12	9	21	21.21
black crappie	11	22	33	24.09	2	5	7	7.07
bluegill	1	1	2	1.46	0	1	1	1.01
smallmouth bass	0	0	0	..	0	1	1	1.01
northern pike	0	0	0	..	0	0	0	..
walleye	0	1	1	0.73	0	0	0	..
channel catfish	0	1	1	0.73	0	0	0	..
green sunfish	6	0	6	4.38	3	0	3	3.03
TOTAL	..	..	137	100.0	..	..	99	100.0

Gardner Pond: % Native: 1.46
% Nonnative: 98.54

Hotspot Pond: % Native: 2.02
% Nonnative: 97.98

Table 4. Relative abundance of fishes collected from Gardner and Hotspot ponds with the three different gear types, April, June, and July 1996. Refer to Appendix C; Tables C.1.-C.3. for breakdown of relative abundance and CPUE of fishes collected with each gear type.

Common Name	Electrofishing		Trap Nets		Trammel Nets		Totals	
	No. of fish	Percentage Composition	No. of fish	Percentage Composition	No. of fish	Percentage Composition	No. of fish	Percentage Composition
Native								
flannemouth sucker	0	--	99	52.1	91	47.9	190	100
bluehead sucker	0	--	1	50.0	1	50.0	2	100
roundtail chub	0	--	18	60.0	12	40.0	30	100
Colorado squawfish	0	--	11	55.0	8	45.0	19	100
Nonnative								
black bullhead	48	8.3	449	78.1	78	13.6	575	100
common carp	292	75.5	68	17.6	27	7.0	387	100
largemouth bass	52	57.8	36	40.0	2	2.2	90	100
white sucker	13	2.7	320	66.1	151	31.2	484	100
black crappie	8	4.5	164	93.2	4	2.3	176	100
bluegill	15	15.0	83	83.0	2	2.0	100	100
smallmouth bass	0	--	1	50.0	1	50.0	2	100
northern pike	0	--	0	--	1	100.0	1	100
walleye	0	--	1	100.0	0	--	1	100
channel catfish	1	9.1	7	63.6	3	27.3	11	100
green sunfish	17	16.0	83	78.3	6	5.7	106	100
Hybrid sucker								
white sucker X flannemouth sucker	1	25.0	2	50.0	1	25.0	4	100
white sucker X bluehead sucker	1	14.3	5	71.4	1	14.3	7	100
bluehead sucker X flannemouth sucker	0	--	0	--	0	--	0	0
TOTAL	448	--	1,348	--	389	--	2,185	--

recaptured from Gardner Pond and 196 fishes initially marked in Hotspot Pond were recaptured from Hotspot Pond (Appendix D; Tables D.1.-D.3.).

Mark and recapture data revealed that some species moved between the two ponds via the connection channel of each pond and the river. Thirty-three fish that were initially captured and marked in Hotspot Pond were later recaptured in Gardner Pond; 29 fish that were initially captured and marked in Gardner Pond were recaptured in Hotspot Pond (Appendix D; Tables D.1.-D.3.). Mark and recapture data indicated that nonnative fishes moved the most between the two ponds. Common carp, largemouth bass, white sucker, bluegill, and black crappie all moved from one pond to the other sometime between April and July. White sucker moved the most--39 moved between the two ponds whereas only six adult largemouth bass moved between the two ponds. Only one native fish, the roundtail chub, was observed to move between the two ponds. Of the 23 roundtail chub captured and marked from Gardner Pond, three fish were later captured in Hotspot Pond. No fish was recaptured more than three times, and only two white sucker were recaptured three times.

Inventory of Small-sized Fishes

Seining captured mostly small, young-of-the-year fish. However, sub-adult and adult fishes of some small-sized fish species such as red shiner, sand shiner, and western mosquitofish were also captured. Of the 21 fishes collected during the entire study with all gear types, nine species were collected with seines (Table 5). All were nonnatives.

Table 5. Catch statistics for fishes collected by seining from Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, 13 August 1996.

Common Name	Number of fish	Gardner Pond		Number of fish	Hotspot Pond	
		Percentage Composition	CPUE (Fish/10m ²)		Percentage Composition	CPUE (Fish/10m ²)
Native						
flannemouth sucker	0	--	--	0	--	--
bluehead sucker	0	--	--	0	--	--
roundtail chub	0	--	--	0	--	--
Colorado squawfish	0	--	--	0	--	--
Nonnative						
black bullhead	270	32.45	5.11	8	1.94	0.11
common carp	3	0.36	0.06	3	0.73	0.04
largemouth bass	144	17.31	2.72	143	34.62	1.95
white sucker	0	--	--	0	--	--
black crappie	329	39.54	6.22	90	21.79	1.22
bluegill	1	0.12	0.02	0	--	--
channel catfish	0	--	--	0	--	--
green sunfish	21	2.52	0.40	32	7.75	0.44
western mosquitofish	62	7.45	1.17	125	30.27	2.05
red shiner	2	0.24	0.38	5	1.21	0.07
sand shiner	0	--	--	7	1.69	0.10
TOTAL	832	100.0	--	413	100.0	--
MEAN	--	--	15.74	--	--	5.64

Number of samples: Gardner Pond: 5
Hotspot Pond: 5
Total Area Sampled: Gardner Pond: 528.6 m²
Hotspot Pond: 732 m²

Composition and Abundance

Both ponds were sampled 13 August to assess annual reproduction of young-of-the-year fish of the more common nonnative fishes. A total of 832 fish representing eight species were collected in Gardner Pond; 413 fish representing eight species were collected in Hotspot Pond (Table 5). Seining in August revealed that five nonnative fish species (black bullhead, largemouth bass, black crappie, green sunfish, and western mosquitofish) had successfully reproduced in both ponds. Numerically, the eight fish species collected in descending order in Gardner Pond were black crappie (40%), black bullhead (32%), largemouth bass (17%), western mosquitofish (7%), green sunfish (3%), common carp, red shiner, and bluegill (each < 1%; Figure 6). In Hotspot Pond, largemouth bass (35%), western mosquitofish (30%), black crappie (22%), green sunfish (8%), black bullhead and sand shiner (each 2%), red shiner (1%), and common carp (< 1%);

SPECIES COMPOSITION **Seining--August 1996**

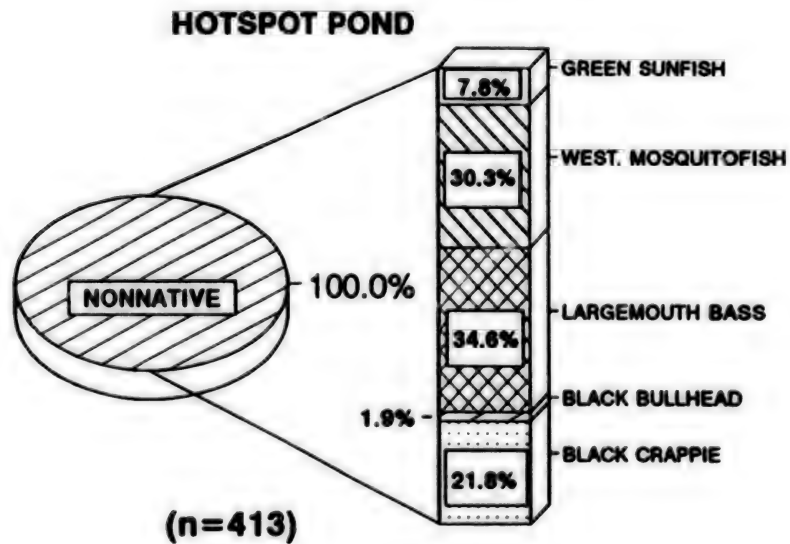
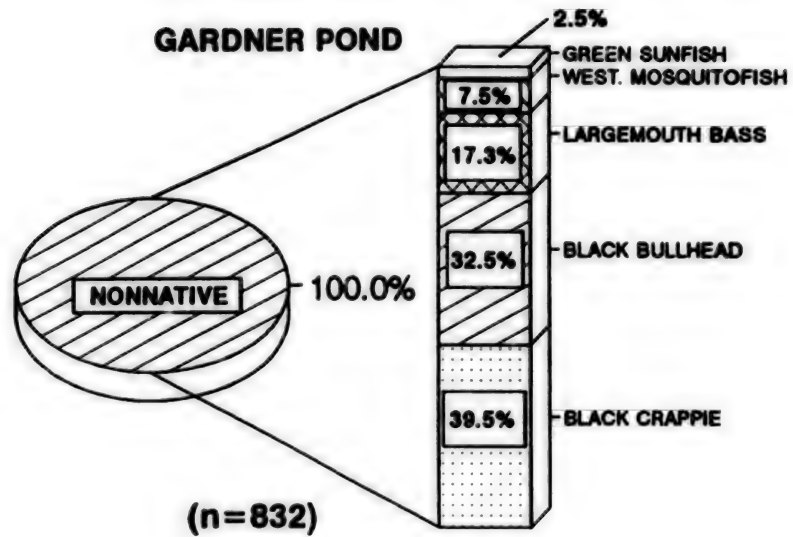


Figure 6. Species composition for five most common nonnative fishes collected by seining from Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, 13 August 1996. Refer to Table 5.

Figure 6). Densities (F/10m²) for the five most common fishes collected in Gardner Pond were: black crappie (6.2), black bullhead (5.1), largemouth bass (2.7), western mosquitofish (1.2), and green sunfish (0.4). For Hotspot Pond, largemouth bass (2.0), western mosquitofish (2.1), black crappie (1.2), green sunfish (0.4), and black bullhead (0.1; Table 5).

Size Structure of Common Fishes

Length-frequency histograms were plotted for four nonnative fishes collected in each pond: largemouth bass, black bullhead, black crappie, and western mosquitofish. The length-frequency distributions for the first three species represent young-of-the-year fish whereas the length-frequency histogram for western mosquitofish represents young-of-the year as well as sub-adult and adult age groups. The size distribution for largemouth bass was similar for both ponds (Appendix E; Figure E.1.). The mean TL was 61 mm (34-99 mm) and 63 mm (37-95 mm) for largemouth bass from Gardner and Hotspot ponds, respectively. Most of the young-of-the-year black bullhead were collected from Gardner Pond. The mean TL was 37 mm (26-53 mm; Appendix; Table E.2.). It was difficult to distinguish age groups for western mosquitofish, although it was apparent that they had reproduced in 1996. The mean TL for all age groups of western mosquitofish collected in Gardner and Hotspot ponds was 34 mm (21-47 mm) and 36 mm (15-56 mm), respectively (Appendix; Table E.3.).

A bimodal, length-frequency distribution for black crappie suggested that this species could have spawned twice in both ponds during 1996 (Appendix E; Table E.4.). Another possibility was that the second bimodal peak (60-69 mm TL) represents Age-1 fish. The mean back-calculated length data for black crappie produced in ponds and reservoirs in northwestern Colorado at annulus I was 76 mm (Personal communication, Patrick Martinez). The same pattern for black crappie was observed for both ponds. The two modal length classes for Gardner Pond were 20-29 mm and 50-59 mm whereas the two length classes for Hotspot Pond were 30-39 mm and 60-69 mm. This indicated that spawning may have occurred in Hotspot Pond before Gardner Pond. Hotspot Pond is shallower than Gardner Pond and water temperatures probably warmed sooner and faster in Hotspot allowing fish to spawn earlier and grow more rapidly.

CONCLUSIONS

The following were conclusions from the research of this study:

1. The species composition of both ponds was predominantly nonnative during three sampling periods that coincided with pre-runoff, runoff, and post-runoff of the Colorado River.
2. Native fishes used the two connected ponds mostly during runoff.
3. Five species of sub-adult and adult nonnative fishes moved between the two ponds that were connected to the river. White sucker and largemouth bass migrated the most between the two ponds. Roundtail chub was the only native fish to move between the two ponds.

4. Within four months following draining, removal of nonnative fishes, and construction of a connection channel, nonnative fishes invaded and recolonized Gardner Pond. Within eight months, five species of nonnative fishes had successfully reproduced in Gardner Pond. Two conclusions were evident: a) Gardner Pond had again become a haven for nonnative fishes, and b) nonnative fishes are extremely resilient. Any ponds, whether in the 10-, 50-, or 100-year floodplain with bottoms irregularly shaped and contoured as depressions, provide perennial, off-channel habitats for nonnative fishes to grow and reproduce. Such ponds that are connected to the river allow sub-adult and adult nonnative fishes uninhibited access to the river and to other off-channel habitats connected to the river. Although such ponds are used by native fishes only during runoff, nonnative fishes appear to benefit more from such perennial, lentic habitats. In any event, ponds with depressions provide a constant supply source of nonnative fish that can potentially escape to the mainstem river.
5. Hotspot Pond did not drain following runoff in 1996. Therefore, an accurate assessment of whether nonnative fish populations could be reduced or eliminated was not possible. Usually, during low-water years, this pond is almost entirely dewatered by late-August or early-September leaving only a mud flat at the upper end. Irrigation waste water that flows through the pond to the river is the only source of water. The only habitat available for fish is near the connection channel near the river. However, during high-water years, such as 1996, this pond does not completely drain leaving adequate water depths for fish to survive during the winter. In addition, groundwater levels during high-water years probably help retain pond water levels longer than during low-water years.
6. If ponds are reclaimed, steeper bottom slopes than that found in Hotspot Pond will be required for ponds to drain during high-flow years to reduce or eliminate perennial habitat for nonnative fishes.

ECOLOGICAL FUNCTIONS OF A RIVERINE SYSTEM

Welcomme (1985) and Ward and Stanford (1995) emphasized that the diversity, resilience, and integrity of large river ecosystems are related to the connectivity of the main channel and its associated floodplain. However, there is an increasing trend in regulating streamflows of large river systems to increase the productivity of basins for agriculture and increase safety for human occupation. Such modification of the aquatic environment generally adversely affects the fish stocks in large river systems (Welcomme 1985). Welcomme stated that the majority of riverine fishes have been extremely sensitive to modifications in the flood cycle and other environmental alterations caused by human activities to regulate streamflows. He also pointed out that substantial shifts in the composition of the fish community and the introduction of nonnative species result in uncertainty of restoring fish assemblages by simple natural processes. Welcomme emphasized that planning in river management must include the floodplain since these areas are essential to maintain fisheries.

The concepts of the river continuum (Vannote et al. 1980) and flood pulse (Junk et al. 1989) apply to the Upper Colorado River Basin. The river continuum concept applies to the headwaters and high gradient, restricted meander canyon reaches whereas the flood pulse concept applies to low gradient, unrestricted reaches that form floodplains in the broad valley reaches. Lotic systems not only transfer organic matter from upstream reaches in arid or semi-arid regions (i. e., continuum concept) but also deposit this material in floodplains where high productivity of invertebrates periodically enters the river (i. e., flood pulse concept). Shallow floodplain habitats become much warmer than the adjacent river, increasing the productivity for phytoplankton and development of a food web (Welcomme 1979). Slow growth and higher mortality of endangered Colorado River fishes has been attributed to lower water temperatures in the Upper Colorado River Basin (Kaeding and Osmundson 1988). Floods and floodplains are now understood to be essential components of river systems (Bayley 1991; Petts and Maddock 1994; Sedell et al. 1989). The energy dynamics of large rivers is strongly influenced by floodplain habitats (Sedell et al. 1989) where productivity is higher than habitats in river channels (Hynes 1970; Welcomme 1985; Welcomme 1989). The spawning strategies of fishes in many tropical and some temperate areas are correlated with the flood pulse that is associated with high productivity in shallow, flooded areas where organic matter is retained (Junk et al. 1989). Welcomme (1985) stated that the shallow littoral zone of floodplain habitats produce higher densities of zooplankton when compared with the entire floodplain area.

STRATEGIES TO ENHANCE OR RESTORE FLOODED BOTTOMLAND HABITATS IN THE UPPER COLORADO RIVER BASIN

The use of floodplains for agriculture, housing, and industrial use has increased in demand and these uses have increased river pollution (Welcomme 1985). Fish assemblages in large rivers vary considerably and are often related to the connectivity of the floodplain with the main channel (Copp 1989). Many riverine fish species exhibit seasonal movements into inundated floodplain habitats for spawning, rearing, and foraging (Finger and Stewart 1987; Lambou 1963; Ross and Baker 1983). Seasonal flooding of bottomlands are important in sustaining various fish species that are characteristic of river channels (Baker and Killgore 1994). Baker and Killgore emphasize that the pattern of flooding appears to be of paramount importance in structuring wetland fish communities and that fish may spread over large areas of the floodplain during high streamflows. The lateral movement of fish on the floodplain decreases exponentially with reductions in streamflow (Kwak 1988) and recruitment may not occur if water levels remain low (Starrett 1951). During low streamflows, backwater habitats become important in sustaining fish populations. Some fish species have modified their behavior to use backwaters and secondary channels of large rivers as substitutes for floodplain habitats as nurseries (Welcomme 1985). Species that cannot adapt to the riverine environment when floodplain habitats are no longer available will perish.

The restoration of large floodplain rivers will require at least partial recovery of the natural hydrograph based on the current knowledge of such systems (Bayley 1991; Hesse 1995; Ward and Stanford 1995). But, because of other demands on the use of Colorado River water, extensive flooding of bottomland habitats

will not be possible. Wydoski and Wick (1996) discussed in depth the ecological importance of floodplains to riverine fish communities and identified strategies to enhance or restore flooded bottomland habitats to assist recovery of endangered fishes in the Upper Colorado River Basin. They felt that it is imperative to integrate the control of nonnative fishes and augmentation/restoration stocking of captive-reared razorback sucker with habitat enhancement/restoration efforts. Enhancement or restoration of biological, chemical, and physical conditions that are perceived to be important in nursery sites for razorback sucker can be accomplished by: 1) removal of levees to allow periodic flooding of lowlands, 2) providing a longer duration of inundation in floodplains, embayments, and backwaters by reoperation of releases from reservoirs, and 3) reconnection of the main channel with off-channel oxbow lakes and ponds. The removal of levees coupled with higher spring releases that mimic the historic hydrograph from upstream dams provided the best way to reconnect mainstem and tributary rivers with productive floodplain areas. Such removal should be done on low floodplain terraces on public properties that can be easily reconnected with the main channel and where thorough, followup evaluations can be made.

However, some nonnative fishes that are established in the upper basin will flourish in productive off-channel habitats. Tyus et al. (1982) estimated that 76.4% of the fish community in the Upper Colorado River Basin is composed of nonnative fishes. Predation and competition on larval razorback sucker by nonnative fish is probably the primary factor that drastically reduces or prevents recruitment of this species today. If the duration of inundation of off-channel habitats is short, razorback suckers will not grow to a size where predation and competition by nonnative fishes is no longer a principal factor in their survival. Floodplain habitats that are ephemeral will not provide enough time for razorback sucker larvae to reach a length of 1 inch. Since nonnative fish species dominate backwater habitats (up to 90-99% based on ISMP data [McAda et al. 1994]), razorback sucker larvae that enter the river as ephemeral floodplains recede will be extremely vulnerable to predation since razorback sucker larvae constitute the only wiggling food items in the spring. Based on Papoulias and Minckley's work (1990), about 2 months is required for razorback suckers to reach a length of 1 inch. Razorback sucker that are about 1-inch long are no longer vulnerable to predation by some predators such as red shiners based on the gape size work by Todd Crowl. If the duration of flooding these habitats is longer, nonnative fishes will flourish and continue to adversely affect larval and juvenile razorback sucker. Wydoski and Wick (1996) agreed with Stanford (1994) who believed that the negative nonnative fish interactions may limit the recovery of razorback sucker regardless of possible streamflow provisions. They also felt that recovery of this species may be limited unless adequate control measures can be implemented in upstream, and particularly in downstream reaches of main channels, where razorback sucker larvae drift as the flooded areas recede following high streamflows. If adequate control of nonnative fishes cannot be achieved, they suggest that human intervention may be required to rear razorback suckers in predator-free, off-channel habitats so that their populations can be maintained through augmentation stocking.

Of the four "large-river" endemic, warmwater fishes that are listed endangered in the Upper Colorado River Basin, the Recovery Program considers the razorback sucker the highest priority species for recovery. While razorback

sucker adults are flexible in their use of habitats, early life-history stages of this species require inundated floodplains to grow and survive (Tyus and Karp 1989; 1990; 1991). Enhancement or restoration of floodplain habitats through reconnection with upper basin rivers will improve the productivity of the ecosystem for zooplankton and benthic invertebrates required by the early life stages of the razorback sucker. Studies of backwaters of the Colorado and Mississippi rivers (Edwards 1982; Schnick et al. 1982; Saiki 1976; Saiki et al. 1976; Kennedy and Tash 1979a,b; Ohmart et al. 1975) indicate that some connectivity of backwaters and ponds with river channels are important. Direct openings to the river permit water exchange that can prevent stagnation and oxygen depletion, renew fresh organic material and nutrients, flush out harmful contaminants (pesticides, herbicides, and trace elements) that may have accumulated, provide fish access, and allow export of materials such as detritus, plankton, and aquatic invertebrates to the river (Matter and Mannan 1988).

Wydoski and Wick (1996) recommended that any enhancement or restoration endeavors must be made through experiments that are thoroughly evaluated using the adaptive management approach. Attempts to restore large areas of floodplain habitats would preclude adequate evaluations and refinements using the adaptive management approach. Limited areas that are enhanced or restored should be thoroughly evaluated and refinements made as necessary to determine the responses of the endangered and nonnative fishes to such efforts. Experiments conducted first on public property would preclude extremely high flow releases that would cause sociological problems associated with the flooding of private agricultural lands and the production of mosquitoes that could pose human health concerns. If the experiments performed on public property are successful and it is determined that more floodplain habitat is needed for restoration, then leasing of private lands can be explored and implemented.

ALTERNATIVE MANAGEMENT OPTIONS

The following management options should be considered by the Recovery Program as habitat improvements to assist recovery of Colorado River endangered fishes.

1. Coordinate Recovery Program Efforts with the U. S. Army Corps of Engineers, Colorado Mined Land Reclamation, and Gravel-pit Companies to Restore Gravel-Mining Areas to Function as Historical Terraces to Benefit Native Fishes. Rip-rap in levees and dikes, constructed to protect gravel-mining activities and to prevent flooding in low-lying areas along some stream reaches in the Grand Valley along the Upper Colorado River, has reduced the width of the river channel. Implementing new procedures to reclaim ponds as sloped terraces that flood and drain seasonally to benefit endangered and native fishes would have to be coordinated with and mutually agreed upon by gravel-mining companies, Colorado Mined Land Reclamation, and Recovery Program participants. Reclamation procedures should include the specifications for designing and contouring the bottom in these ponds to slope toward the river to allow seasonal flooding and draining. These conditions should be identified when mining permits are initially issued. The U. S. Army Corps of Engineers now has the

jurisdictional authority to regulate excavation of fill material in wetland areas and below ordinary high water in riverine reaches where critical habitat has been designated for endangered fishes.

In the future where possible, as a condition of being granted a 404 permit, gravel-mining companies that create ponds in wetlands adjacent to the river could be required to create stepped terraces leading to the river during their mining activities so that the terraces drain when high streamflows reside. Eventually, the ponds would then be reconnected to the river when mining activities are completed as part of their reclamation procedures. Whenever floodplain habitats are connected to the river, hydrological access for fish should be by surface connection. Underground culverts and pipes should be avoided because some native fish might be shy and will not use such structures.

2. Notch Dikes and Levees Protecting Gravel Pits. Reconnect former floodplain habitats without deep depression ponds with the river to enhance or restore the natural function of the river ecosystem. Such former floodplain habitats have been separated from the river by levee construction so it would be cost-effective and practical to acquire rights to use land through easements or fee-title so the floodplain could be reconnected with the river by excavating a notch. Although it might be desirable to implement recommended river flows that would inundate floodplains in the spring during May and June to provide off-channel habitat for endangered fish, adequate flows might not be available frequently enough to benefit recovery of the endangered fishes. Therefore, notching old levees and dikes at strategic locations could provide some level of protection from flooding to agricultural land, and residential and recreational structures (i. e., set-back dikes) and also provide access to floodplain habitats to various life stages of endangered fishes. Dikes and levees constructed to protect gravel-mining operations could be removed following gravel mining to permit reconnection of the floodplain and the river. The floodplain could then function as it did historically, recreating new in-channel habitats. Some of the features created would be flow-through side channels that might create a complex of habitat types.

An ancillary benefit for modifying gravel-pits protected by levees and dikes to allow these habitats to communicate with the river during runoff is flood control. In addition to isolating off-channel, productive areas from aquatic organisms, levees and dikes have reduced the channel width and thus the river's ability to convey large volumes of water during runoff. In some areas protected by levees and dikes, runoff water now inundates adjacent low-lying areas at lower discharges than did historically. Flood-control management strategies would be to notch levees and dikes to allow inundation of low-lying areas and also reclaim gravel-pit ponds as sloped terraces or side channels. Restoring gravel pits to function as historical terraces or side channels may not only benefit native fishes but may actually provide county, state, and federal agencies more flexibility in

managing and coping with spring runoff during high-flow years along riparian areas where anthropogenic activity occurs. In low-density population areas, specific riverine reaches that are now constricted could be targeted to be restored as terraces or side channels to serve as "relief valves" and allow runoff waters to spread that would reduce flooding and minimize damage to private land and structures in adjacent areas. It is believed that natural lateral expansion of the floodplain and river-basin management are perhaps the best methods of flood control because of the growing awareness of inadequacies of structural measures to control floods (Welcomme 1985).

3. Acquire Gravel-Pit Ponds Presently Connected to the Mainstem Colorado River. The Recovery Program should investigate opportunities to modify and rehabilitate Hotspot and Pickup ponds (river mile 174.4 and 175.0, respectively) to enhance seasonal habitat for endangered fish and eliminate perennial habitat for nonnative fishes. A portion of Hotspot Pond is owned by the Colorado Division of Parks and Outdoor Recreation. Mr. C. W. Van Wagner, owner of the remainder of the property, should be contacted to determine if this property could be acquired by or donated to the Recovery Program. Pickup Pond is located directly north of the 153-acre parcel of land which was acquired by the Recovery Program in 1996 to preserve habitat for endangered fish and other types of wildlife. The Colorado Department of Natural Resources, Division of Parks and Outdoor Recreation, will assume ownership of Pickup Pond from Mesa County. The Recovery Program should develop a Memorandum of Understanding with the State of Colorado to use Pickup Pond in recovery activities for endangered fish. Any endangered fish recovery activities will have to be compatible with the Mesa County Riverfront Commission because a trail easement is located on the north bank of Pickup Pond.

These two former gravel-pits, presently connected to the mainstem Colorado River, are important floodplain habitats that are used during spring runoff by adult Colorado squawfish. Presently, these ponds do not drain entirely following runoff and retain water. Thus, while used by endangered fish during runoff, if left contoured as the ponds presently are, they will continue to provide perennial havens for nonnative fishes. Recontouring and reshaping the bottom of these two ponds will allow seasonal flooding and draining that will eliminate perennial habitat for nonnative fishes and maintain floodplain habitat that can be used during the spring and early summer for sub-adult and adult Colorado squawfish. If acquisition of floodplain areas is not possible, the Recovery Program should explore entering into agreements with the Mesa County Riverfront Legacy Project that examines broad-range management for multiple uses.

4. Use Deeper Depression Ponds as Grow-Out Ponds for Captive-Rearing of Endangered Fishes. If practical, such ponds should be drained and the bottoms sloped so that seining or trap nets could be used to concentrate and harvest captive-reared fish for stocking. Grow-out ponds provide a "half-way house" for captive-reared razorback sucker juveniles from the hatchery-pond environment where they are reared as

family lots until they can be PIT-tagged and are stocked into the river. In hatchery ponds, the larvae and juveniles feed strictly on zooplankton whereas, in grow-out ponds, they become acquainted with macroinvertebrates so that they may become better foragers following stocking. These grow-out ponds should not be connected to the river by a surface channel or underground outlet pipe, should be predator-free, and secure from flooding to prevent premature escape of endangered fish into river. If a hydrological connection between the pond and river is required, the outlet should be screened. Virginia Acres Pond, immediately north of Pickup Pond, is one such pond that is currently being examined by the Recovery Program to determine its suitability as a grow-out pond for juvenile razorback sucker.

RECOMMENDATIONS

Major recommendations (underscored print) from this study are:

1. Avoid Connecting Isolated Ponds to the River That are Deep Depressions. Floodplain habitat should not contain irregular-shaped, deep depression ponds. These type of habitats are perennial havens for nonnative fishes and provide potential sources for nonnative fishes to escape to the mainstem river. If deep depression habitats cannot be rehabilitated by recontouring and reshaping to provide seasonal, ephemeral habitat, they should be sufficiently diked to prevent escapement of nonnative fishes such as centrarchids and ictalurids.
2. Back-Fill Gravel-Pit Ponds and Reconnect them to the Mainstem River to Flood and Drain Seasonally to Benefit Native Fishes and to Control Nonnative Fishes. As a part of restoration, where feasible and practical, gravel-pit ponds that are relatively shallow could be reclaimed by back-filling, sloped to drain as the river subsides, and allowed to function as an ephemeral wetland. Reconnecting former floodplain habitat to the river to provide off-channel habitats will benefit native fishes. This action would include eradicating nonnative fishes from depression habitats such as former gravel-pit ponds prior to their being back-filled and the pond bottom recontoured so that they steeply slope toward the river to allow seasonal flooding and draining, even during high-water years. The bottom of shallow gravel-pits could be back-filled and recontoured to create stepped terraces leading to the river so that they slope toward the river. These features would then be reconnected to the river to allow fish access during high-flow periods. Modifying these man-made gravel-pit ponds to function as historical terraces may be more cost-effective and practical for managing and controlling nonnative fishes than long-term control measures such as screening ponds, chemical treatment, or mechanical pumping and removal.

LITERATURE CITED

- Baker, J. A., and K. J. Killgore. 1994. Use of a flooded bottomland hardwood wetland in the Cache River system, Arkansas. U. S. Army Corp of Engineers, Washington, D. C. Wetlands Research Program Technical Report WRP-CP-3.
- Bayley, P. B. 1991. The flood pulse advantage and the restoration of river-floodplain systems. *Regulated Rivers: Research and Management* 6: 75-86.
- Burdick, B. D. 1994. Conceptual management plan for habitat enhancement in flooded bottomlands: Gravel Pit at 29-5/8 Road, Colorado River near Grand Junction, Colorado. Final Report prepared for the Recovery Implementation Program for Endangered Fishes in the Upper Colorado River Basin. U. S. Department of the Interior, Fish and Wildlife Service, Colorado River Fishery Project, Grand Junction, CO. 22 pp + Appendix.
- Copp, G. H. 1989. The habitat diversity and fish reproductive function of floodplain ecosystems. *Environmental Biology of Fishes* 26: 1-27.
- Edwards, H. K. 1982. The chain of lakes project along Interstate 80 in Nebraska. Pages 211-214 *in* W. D. Svedarsky and R. D. Crawford, eds. *Wildlife values of gravel pits*. Univ. Minn., Agric. Exp. Stn. Misc. Publ. 17.
- Finger, T. R., and E. A. Stewart. 1987. Response of fishes to flooding regime in lowland hardwood wetlands. Pages 86-92 *in* W. J. Matthews and D. C. Heins, Editors. *Community and evolutionary ecology of North American stream fishes*. University of Oklahoma Press, Norman.
- Grabowski, S. J., and S. D. Hiebert. 1989. Some aspects of trophic interactions in selected backwaters and the main channel of the Green River, Utah: 1987-1988. U. S. Bureau of Reclamation, Research and Laboratory Services Division, Environmental Sciences Section, Denver, CO. 130 pp. + an appendix of 155 pp.
- Graf, W. L. 1985. Fluvial adjustments to the spread of tamarisk on the Colorado Plateau region. *Bulletin of the Geological Society of America* 89: 1491-1501.
- Hesse, L. W. 1995. Water allocation for ecosystem management of the Missouri River. *Regulated Rivers: Research and Management* 11: 299-311.
- Holden, P. B., and C. B. Stalnaker. 1975. Distribution and abundance of mainstream fishes of the middle and upper Colorado River basins, 1967-1973. *Transactions American Fisheries Society* 104: 217-231.
- Irving, D. B., and B. D. Burdick. 1995. Reconnaissance inventory and prioritization of existing and potential bottomlands in the Upper Colorado River Basin 1993-1994. Final Report prepared for the Recovery Implementation Program for Endangered Fishes in the Upper Colorado River Basin. U. S. Department of the Interior, Fish and Wildlife Service, Colorado River Fishery Project, Grand Junction, CO. 57 pages + Appendices A-I.

- Junk, W. J., P. B. Bayley, and R. E. Sparks. 1989. The pulse concept in river floodplain systems. Canadian Fisheries and Aquatic Sciences, Special Publication 106: 110-127.
- Kaeding, L. R., and D. B. Osmundson. 1988. Interaction of slow growth and increased early-life mortality: a hypothesis on the decline of Colorado squawfish in the upstream regions of its historic range. Environmental Biology of Fishes 22(4): 287-298.
- Kennedy, D. M., and J. C. Tash. 1979a. Ecological investigations of backwaters along the lower Colorado River, Part II-Biology. Ariz. Coop. Fish. Res. Unit, Res. Rep. Ser. 79-2. 82 pp.
- Kennedy, D. M., and J. C. Tash. 1979b. Ecological investigations of backwaters along the lower Colorado River, Part III-Overview and management recommendations. Ariz. Coop. Fish. Res. Unit, Res. Rep. Ser. 79-3. 6 pp.
- Kwak, T. J. 1988. Lateral movement and use of floodplain habitat by fishes of the Kankakee River, Illinois. American Midland Naturalist 102: 241-249.
- Lambou, V. W. 1963. The commercial and sport fisheries of the Atchafalaya Basin Floodway. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 17: 256-281.
- Mabey, L. W., and D. K. Shiozawa. 1993. Planktonic and benthic microcrustaceans from floodplain and river habitats of the Ouray Refuge on the Green River, Utah. Department of Zoology, Brigham Young University, Provo, UT. 31 pp.
- Marsh, P. C., and D. R. Langhorst. 1988. Feeding and fate of wild larval razorback sucker. Environmental Biology of Fishes 21: 59-67.
- Matter, W. J., and W. Mannan. 1988. Sand and gravel pits as fish and wildlife habitat in the southwest. U. S. Department of the Interior, Fish and Wildlife Service, Resource Publ. No. 171. 11 pp.
- McAda, C. W. 1977. Aspects of the life history of three catostomids native to the upper Colorado River basin. M. S. Thesis, Utah State University, Logan. 117 pp.
- McAda, C. W., J. W. Bates, J. S. Cranney, T. E. Chart, W. R. Elmblad, and T. P. Nesler. 1994. Interagency standardized monitoring program: Summary of results, 1986-1992. Recovery Implementation Program for Endangered Fishes of the Upper Colorado River Basin, U. S. Fish and Wildlife Service, Denver, CO. 73 pp + Appendices.
- Mitchell, M. J. 1995. Inventory of public and private ponds along the Upper Colorado and Lower Gunnison rivers in Colorado. Prepared for the Colorado Department of Agriculture, Contract No. 95-0021. 38 pp + Appendices.

- Ohmart, R. D., W. O. Deason, and S. J. Freeland. 1975. Dynamics of marsh land formation and succession along the lower Colorado River and management problems as related to wildlife in the arid Southwest. Trans. North Amer. Wildl. Nat. Resour. Conf. 40:240-254.
- Osmundson, D. B., and L. R. Kaeding. 1989. Studies of Colorado squawfish and razorback sucker use of the '15-mile reach' of the upper Colorado River as part of conservation measures for the Green Mountain and Ruedi Reservoir water sales. Colorado River Fishery Project, U.S. Department of the Interior, Fish and Wildlife Service, Grand Junction, CO. 85 pp.
- Osmundson, D. B., and L. R. Kaeding. 1991. Recommendations for flows in the 15-mile reach during October-June for maintenance and enhancement of endangered fish populations in the upper Colorado River. Colorado River Fishery Project, U.S. Department of the Interior, Fish and Wildlife Service, Grand Junction, CO. 82 pp.
- Papoulias, D., and W. L. Minckley. 1990. Food limited survival of larval razorback sucker, *Xyrauchen texanus*, in the laboratory. Environmental Biology of Fishes 29: 73-78.
- Petts, G. E., and I. Maddock. 1994. Flow allocation for in-river needs. Pages 289-307 (Chapter 15) in P. Calow and G. E. Petts, Editors. The rivers handbook. Volume 2. Blackwell Scientific Publications, Oxford.
- Ross, S. T., and J. A. Baker. 1983. The response of fishes to periodic spring floods in a southeastern stream. American Midland Naturalist 109: 1-14.
- Saiki, M. K. 1976. An ecological evaluation of game and fishes at Deer Island Lake, lower Colorado River. Ph.D. thesis, University of Arizona, Tucson. 240 pp.
- Saiki, M. K., D. M. Kennedy, and J. C. Tash. 1976. Recent history of the lower Colorado River and its fish. Ariz. Coop. Fish. Res. Unit, Rep. Ser. 76-2. 28 pp.
- Schnick, R. A., J. M. Morton, J. C. Mochalski, and J. T. Beall. 1982. Mitigation and enhancement techniques for the Upper Mississippi River system and other large river systems. U. S. Fish and Wildlife Service., Resource Publ. 149. 714 pp.
- Sedell, J. R., J. E. Richey, and F. J. Swanson. 1989. The river continuum concept: a basis for the expected ecosystem behavior of very large rivers. Canadian Fisheries and Aquatic Sciences, Special Publication 106: 49-55.
- Stanford, J. A. 1994. Instream flows to assist the recovery of endangered fishes of the Upper Colorado River Basin. U. S. Department of the Interior, National Biological Survey, Biological Report 24. 47 pp.
- Starrett, W. C. 1951. Some factors affecting the abundance of minnows in the Des Moines River, Iowa. Ecology 32: 13-27.

- Tyus, H. M., B. D. Burdick, R. A. Valdez, C. M. Haynes, T. A. Lytle, and C. R. Berry. 1982. Fishes of the Upper Colorado River Basin. Pages 12-70 in W. H. Miller, H. M. Tyus, and C. A. Carlson, Editors. Proceeding of a symposium on fishes of the Upper Colorado River System: Present and future. Western Division, American Fisheries Society, Bethesda, MD.
- Tyus, H. M., and C. A. Karp. 1989. Habitat use and streamflow needs of rare and endangered fishes, Yampa River, Colorado. U.S. Fish and Wildlife Service, Biological Report 89(14). 27 pp.
- Tyus, H. M., and C. A. Karp. 1990. Spawning and movements of razorback sucker, *Xyrauchen texanus*, in the Green River basin of Colorado and Utah. Southwestern Naturalist 35: 427-433.
- Tyus, H. M., and C. A. Karp. 1991. Habitat use and streamflow needs of rare and endangered fishes in the Green River, Utah. Colorado River Fishery Project, U. S. Department of the Interior, Fish and Wildlife Service, Vernal, UT. 45 pages + 9 figures.
- U.S. Fish and Wildlife Service. 1973. Threatened wildlife of the United States. Resource Pub. 114. U. S. Department of the Interior, Fish and Wildlife Service.
- U.S. Fish and Wildlife Service. 1987. Recovery implementation program for endangered fish species in the Upper Colorado River Basin. U.S. Department of the Interior, Fish and Wildlife Service, Region 6, Denver, Colorado. 6 Sections, Various pagination.
- Valdez, R. A., P. G. Mangan, R. P. Smith, and B. C. Nilson. 1982. Upper Colorado River investigations. Pages 101-279 in Part 2, Final Report, U.S. Fish and Wildlife Service and Bureau of Reclamation, Salt Lake City, Utah, Part 2, Colorado River Fishery Project.
- Valdez, R. A., and E. D. Wick. 1983. Natural vs. manmade backwaters as native fish habitat. Pages 519-536 in V. Adams and V. Lamarra, Editors. Aquatic resources management of the Colorado River ecosystem. Ann Arbor Science, Ann Arbor, MI.
- Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Science 37: 130-137.
- Ward, J. V., and J. A. Stanford. 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. Regulated Rivers: Research and Management 11: 105-119.
- Welcomme, R. L. 1979. Fisheries ecology of floodplain rivers. Longman Press, Inc., New York. 317 pp.
- Welcomme, R. L. 1985. River fisheries. Food and Agriculture Organization of the United Nations, Fisheries Technical Paper 262. 330 pp.

Welcomme, R. L. 1989. Floodplain fisheries management. Chapter 8, Pages 209-233 in J. A. Gore and G. E. Petts, Editors. Alternatives in regulated river management. Chemical Rubber Corporation (CRC), Press, Inc., Boca Raton, FL.

Wydoski, R. S., and E. D. Wick. 1994. Enhancement strategies for flooded bottomlands and other habitats in the recovery of endangered fishes in the upper Colorado River basin. Draft report. U. S. Department of Interior, Fish and Wildlife Service and National Park Service, Denver, CO. 80 pp + Appendices.

Wydoski, R. S., and E. D. Wick. 1996. Ecological value of flooded bottomland habitats to endangered fishes in the Upper Colorado River Basin. Recovery Implementation Program for Endangered Fishes in the Upper Colorado River Basin. U. S. Department of the Interior, Fish and Wildlife Service, Denver, CO. 33 pp.

APPENDIX A
Scientific and Common Names of Fishes
Collected From Gardner and Hotspot Pond
During 1996

Table A.1. Scientific and common names, status (native vs. nonnative), and two-letter code of fish collected from Gardner and Hotspot ponds adjacent to the Colorado River (RM 174.4), April, June, July, and August 1996.

Scientific Name	Common Name	Status	Code
Cyprinidae			
<i>Cyprinella lutrensis</i>	red shiner	nonnative	RS
<i>Cyprinus carpio</i>	common carp	nonnative	CP
<i>Gila robusta</i>	roundtail chub	native	RT
<i>Notropis stramineus</i>	sand shiner	nonnative	SS
<i>Ptychocheilus lucius</i>	Colorado squawfish	native	CS ^a
Catostomidae			
<i>Catostomus discobolus</i>	bluehead sucker	native	BH
<i>Catostomus latipinnis</i>	flannelmouth sucker	native	FM
<i>Catostomus commersoni</i>	white sucker	nonnative	WS
<i>C. discobolus</i> X <i>C. latipinnis</i>	bluehead X flannelmouth	native	FB
<i>C. discobolus</i> X <i>C. commersoni</i>	bluehead X white	nonnative	WB
<i>C. commersoni</i> X <i>C. latipinnis</i>	flannelmouth X white	nonnative	WF
Ictaluridae			
<i>Ameiurus melas</i>	black bullhead	nonnative	BB
<i>Ictalurus punctatus</i>	channel catfish	nonnative	CC
Poeciliidae			
<i>Gambusia affinis</i>	western mosquitofish	nonnative	GA
Centrarchidae			
<i>Lepomis macrochirus</i>	bluegill	nonnative	BG
<i>Lepomis cyanellus</i>	green sunfish	nonnative	GS
<i>Micropterus dolomieu</i>	smallmouth bass	nonnative	SM
<i>Micropterus salmoides</i>	largemouth bass	nonnative	LG
<i>Pomoxis nigromaculatus</i>	black crappie	nonnative	BC
Percidae			
<i>Stizostedion vitreum</i>	walleye	nonnative	WE
Esocidae			
<i>Esox lucius</i>	northern pike	nonnative	NP

^a Federally listed as "endangered".

APPENDIX B
Captures of Adult Colorado Squawfish from
Gardner and Hotspot Ponds During 1996

Table C.1. Catch statistics for fish captured in Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, with electrofishing during April, June, and July 1996.

Common Name	Gardner Pond		Hotspot Pond	
	No. of fish	CPUE (Fish/h)	No. of fish	CPUE (Fish/h)
Native				
flannemouth sucker	0	--	0	--
bluehead sucker	0	--	0	--
roundtail chub	0	--	0	--
Colorado squawfish	0	--	0	--
Nonnative				
black bullhead	23	12.64	25	21.37
common carp	127	69.78	165	141.03
largemouth bass	18	9.89	34	29.06
white sucker	9	4.95	4	3.42
black crappie	0	--	8	6.84
bluegill	7	3.85	8	6.84
smallmouth bass	0	--	0	--
northern pike	0	--	0	--
walleye	0	--	0	--
channel catfish	1	0.55	0	--
green sunfish	13	7.14	4	3.42
Sucker hybrids				
white sucker X flannemouth sucker	1	0.55	0	--
white sucker X bluehead sucker	0	--	1	0.85
bluehead sucker X flannemouth sucker	0	--	0	--
TOTAL	199	--	249	--

Hours electrofished: Gardner Pond: 1.82.
Hotspot Pond: 1.17.

Table C.2. Catch statistics for fish captured in Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, with trap nets during April, June, and July 1996.

Common Name	Gardner Pond		Hotspot Pond	
	No. of fish	CPUE (Fish/h)	No. of fish	CPUE (Fish/h)
Native				
flannemouth sucker	81	0.18	18	0.05
bluehead sucker	1	< 0.01	0	--
roundtail chub	12	--	6	0.02
Colorado squawfish	8	--	3	< 0.01
Nonnative				
black bullhead	226	0.49	223	0.60
common carp	30	0.07	38	0.10
largemouth bass	5	0.01	31	0.08
white sucker	125	0.27	195	0.52
black crappie	57	0.12	107	0.29
bluegill	22	0.05	61	0.16
smallmouth bass	0	--	1	< 0.01
northern pike	0	--	0	--
walleye	1	< 0.01	0	--
channel catfish	2	< 0.01	5	0.01
green sunfish	59	0.13	24	0.06
Sucker hybrids				
white sucker X flannemouth sucker	0	--	2	< 0.01
white sucker X bluehead sucker	4	< 0.01	1	< 0.01
bluehead sucker X flannemouth sucker	0	--	0	--
TOTAL	633	--	715	

Hours netted: Gardner Pond: 457.4.
Hotspot Pond: 374.4.

Table C.3. Catch statistics for fish captured in Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, with trammel nets during April, June, and July 1996.

Common Name	Gardner Pond		Hotspot Pond	
	No. of fish	CPUE (Fish/h)	No. of fish	CPUE (Fish/h)
Native				
flannemouth sucker	77	4.61	14	0.75
bluehead sucker	0	--	1	0.05
roundtail chub	11	0.66	1	0.05
Colorado squawfish	5	0.30	3	0.21
Nonnative				
black bullhead	22	1.32	56	2.99
common carp	8	0.48	19	1.02
largemouth bass	0	--	2	0.11
white sucker	79	4.73	72	3.85
black crappie	0	--	4	0.21
bluegill	1	0.06	1	0.05
smallmouth bass	1	0.06	0	--
northern pike	0	--	1	0.05
walleye	0	--	0	--
channel catfish	1	0.06	2	0.11
green sunfish	3	0.18	3	0.16
Sucker hybrids				
white sucker X flannemouth sucker	1	0.06	0	--
white sucker X bluehead sucker	1	0.06	0	--
bluehead sucker X flannemouth sucker	0	--	0	--
TOTAL	210	--	179	--

Hours netted: Gardner Pond: 16.7.
Hotspot Pond: 18.7.

APPENDIX D

**Number of Fish Recaptured from Gardner and Hotspot Ponds
during Pre-runoff, Runoff, and Post-runoff
of the Colorado River 1996**

Table D.1. Number of fish recaptured in Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, during pre-runoff, April 1996.

PRE-RUNOFF (4/9 - 4/17)

Common Name	Gardner Pond		Hotspot Pond	
	From Gardner ^a	From Hotspot ^b	From Hotspot ^c	From Gardner ^d
Native				
flannemouth sucker	4	0	4	0
bluehead sucker	0	0	0	0
roundtail chub	3	2	0	0
Colorado squawfish	1	0	0	0
Nonnative				
black bullhead	25	0	31	0
common carp	13	0	4	4
largemouth bass	0	0	6	4
white sucker	23	11	14	6
black crappie	10	0	21	0
bluegill	2	2	13	4
smallmouth bass	0	0	0	0
northern pike	0	0	0	0
walleye	0	0	0	0
channel catfish	0	0	0	0
green sunfish	0	0	0	0
TOTAL	81	15	93	18

^a Initially captured in Gardner Pond and recaptured in Gardner Pond.

^b Initially captured in Hotspot Pond but later recaptured in Gardner Pond.

^c Initially captured in Hotspot Pond and recaptured in Hotspot Pond.

^d Initially captured in Gardner Pond but later recaptured in Hotspot Pond.

Table D.2. Number of fish recaptured in Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, during runoff, June 1996.

RUNOFF (6/3 - 6/12)

Common Name	Gardner Pond		Hotspot Pond	
	From Gardner ^a	From Hotspot ^b	From Hotspot ^c	From Gardner ^d
Native				
flannemouth sucker	6	0	0	0
bluehead sucker	0	0	0	0
roundtail chub	3	1	0	0
Colorado squawfish	1	0	0	0
Nonnative				
black bullhead	1	0	12	1
common carp	0	0	1	0
largemouth bass	0	0	4	0
white sucker	2	9	33	5
black crappie	2	0	20	0
bluegill	1	0	3	0
smallmouth bass	0	0	0	0
northern pike	0	0	0	0
walleye	0	0	0	0
channel catfish	0	0	0	0
green sunfish	7	0	2	1
TOTAL	23	10	75	7

^a Initially captured in Gardner Pond and recaptured in Gardner Pond.

^b Initially captured in Hotspot Pond but later recaptured in Gardner Pond.

^c Initially captured in Hotspot Pond and recaptured in Hotspot Pond.

^d Initially captured in Gardner Pond but later recaptured in Hotspot Pond.

Table D.3. Number of fish recaptured in Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, during post-runoff, July 1996.

POST-RUNOFF (7/16 - 7/24)

Common Name	Gardner Pond		Hotspot Pond	
	From Gardner ^a	From Hotspot ^b	From Hotspot ^c	From Gardner ^d
Native				
flannelmouth sucker	0	0	0	0
bluehead sucker	0	0	0	0
roundtail chub	0	0	0	0
Colorado squawfish	0	0	0	0
Nonnative				
black bullhead	1	0	5	0
common carp	1	0	4	0
largemouth bass	1	2	2	0
white sucker	4	4	12	4
black crappie	1	2	2	0
bluegill	0	0	2	0
smallmouth bass	0	0	1	0
northern pike	0	0	0	0
walleye	0	0	0	0
channel catfish	0	0	0	0
green sunfish	0	0	0	0
TOTAL	8	8	28	4

^a Initially captured in Gardner Pond and recaptured in Gardner Pond.

^b Initially captured in Hotspot Pond but later recaptured in Gardner Pond.

^c Initially captured in Hotspot Pond and recaptured in Hotspot Pond.

^d Initially captured in Gardner Pond but later recaptured in Hotspot Pond.

APPENDIX E
Total Length Frequency of Four Nonnative Fishes Collected
with Seines in Gardner and Hotspot Ponds During
August 1996

Largemouth Bass

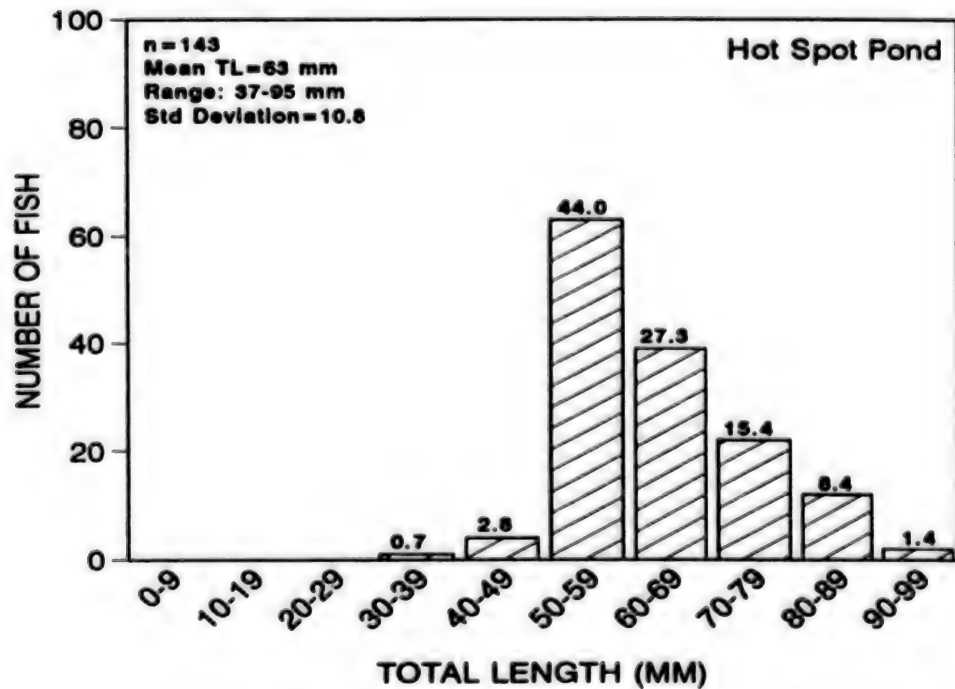
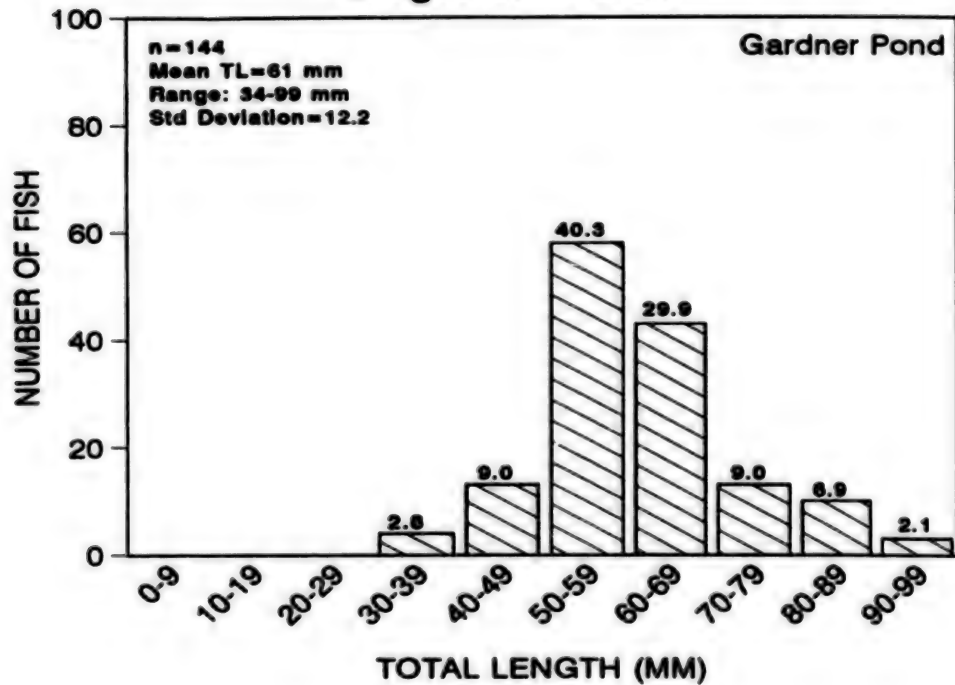


Figure E.1. Total length (mm) frequency composition of young-of-the-year largemouth bass collected by seining from Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, 13 August 1996. Note: numbers above bars represent percent.

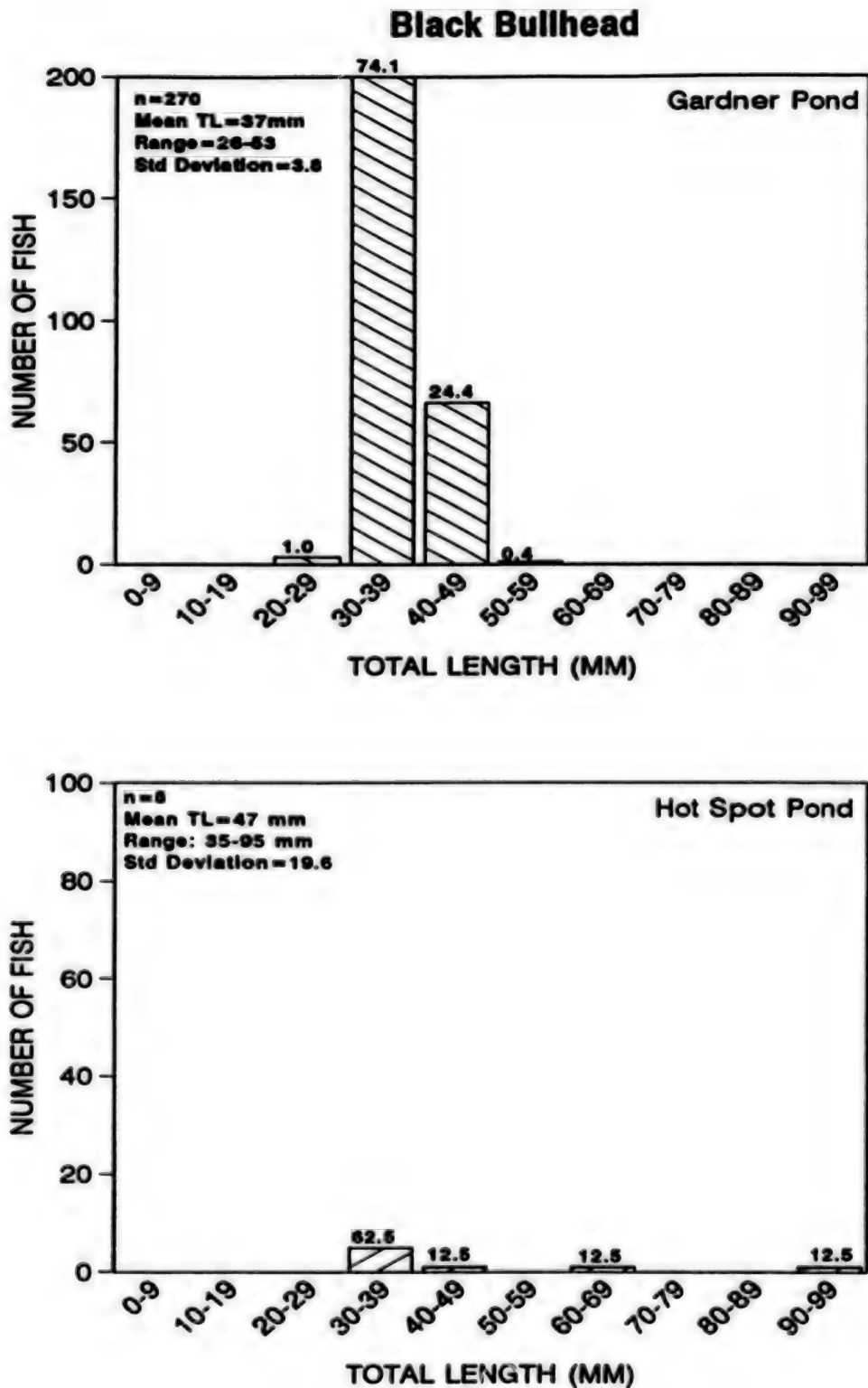


Figure E.2. Total length (mm) frequency composition of young-of-the-year black bullhead collected by seining from Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, 13 August 1996. Note: numbers above bars represent percent.

Western Mosquitofish

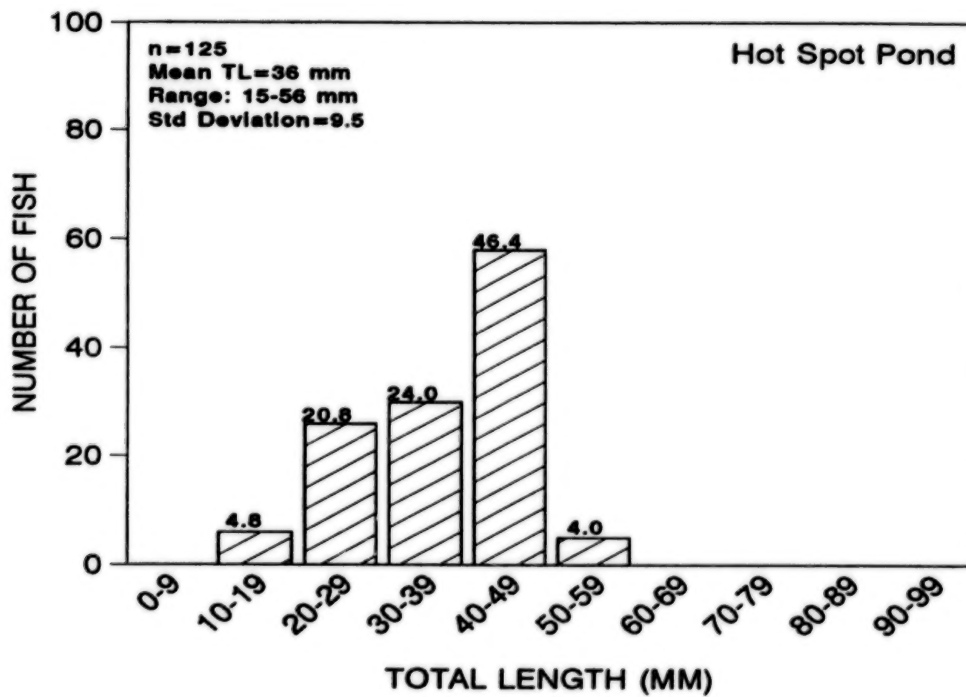
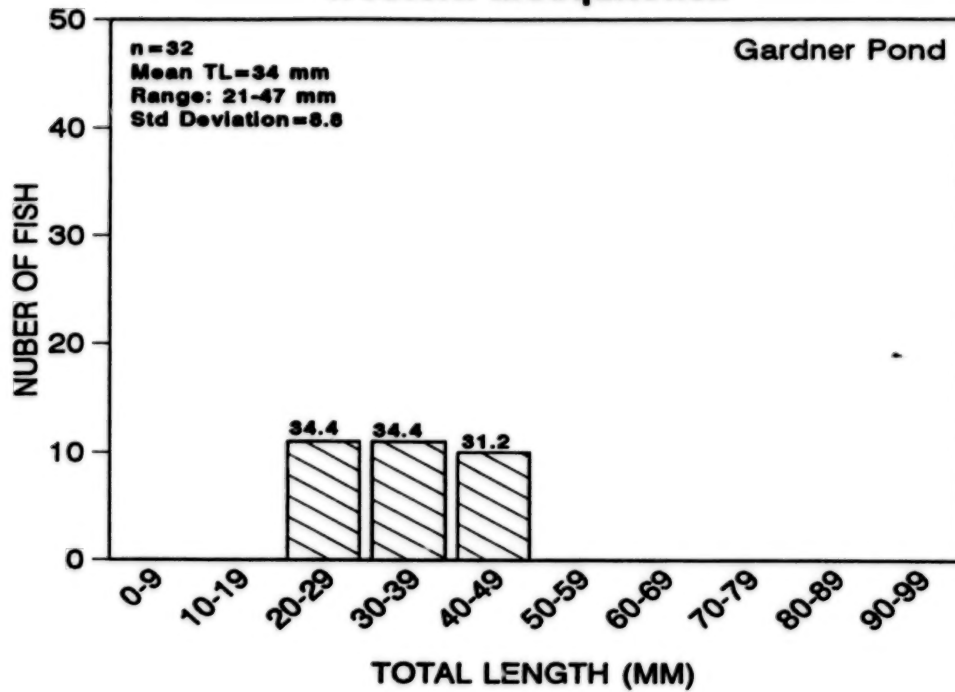


Figure E.3. Total length (mm) frequency composition of western mosquitofish collected by seining from Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, 13 August 1996. Note: numbers above bars represent percent.

Black Crappie

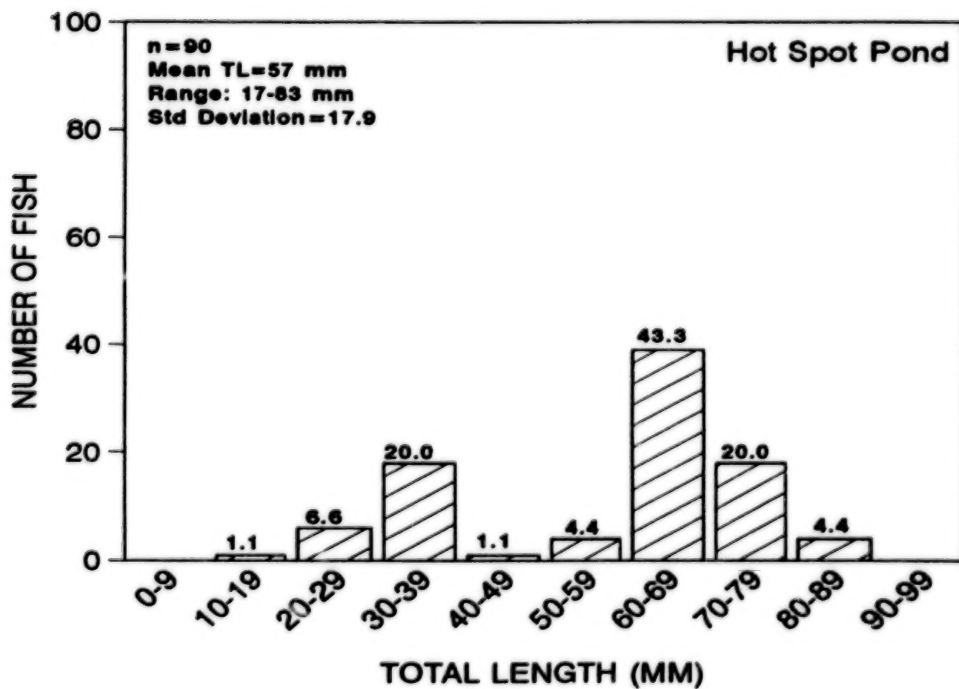
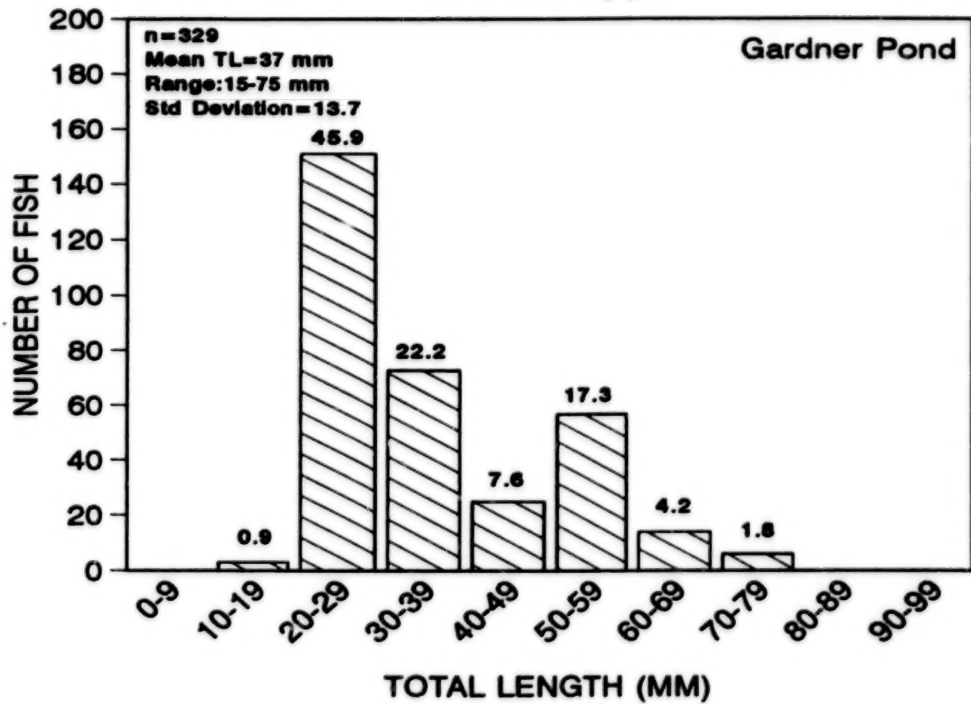


Figure E.4. Total length (mm) frequency composition of young-of-the-year black crappie collected by seining from Gardner and Hotspot ponds adjacent to the Colorado River near Grand Junction, Colorado, 13 August 1996. Note: numbers above bars represent percent.

END

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